UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 13

KANKAKEE COUNTY SOILS

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URBANA, ILLINOIS, JUNE, 1916

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to anyone else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles, in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

KANKAKEE COUNTY SOILS

By Cyril G. Hopkins, J. G. Mosier, E. Van Alstine, and F. W. Garrett

Kankakee county is located on the eastern line of the state 125 miles south of the northern boundary. It has been covered completely by two glaciations, or ice sheets, the Illinoisan and the early Wisconsin.

Altho the county is traversed by two of the large rivers of the state, the Kankakee and the Iroquois, it presents no great variations in topography. The greatest differences may be seen in the western, or northwestern, part of the county as the result of erosion by the Kankakee river. The county may be divided roughly into three regions; that of the early Wisconsin glaciation, the southwestern part; that of the late Wisconsin glaciation, the northeastern part; and the former lake, or swamp, region. These divisions are more physiographic than topographic, and will be considered more fully later. Outside the swamp area the topography is largely morainal, having been produced by the glaciers, but it is not of an extreme type. Dune topography prevails in some parts of the lake, or swamp, area.

Glaciations of Kankakee County

The first ice sheet to invade Kankakee county was the Illinoisan, but what its action was cannot now be seen because of the effect of the subsequent early Wisconsin glacier, which there is no doubt covered the entire county. As the early Wisconsin glacier receded, it produced the Marseilles moraine, which may be seen in the southwestern and southern parts of the county, just north of Chebanse and Cabery and west of the Iroquois river. (See state soil map, Bulletin 123.) Any other moraines that may have been produced by this glaciation were obscured by the late Wisconsin, which followed the recession of the early Wisconsin. This later ice sheet covered that part of the county which lies east and north of the Iroquois-Kankakee river, building up a principal moraine in the southern part of the county in the vicinity of St. Anne and a rather secondary moraine northwest from the city of Kankakee.

The glaciers, or ice sheets, originated in Canada, and from there pushed southward picking up and carrying along large quantities of material of all kinds and sizes, varying from the finest clay to masses of rock weighing tons. As the ice advanced, the coarse materials ground over the surface rock and against themselves, producing immense quantities of rock flour; and when the glacier melted, this mixture consisting of clay, silt, sand, gravel, and boulders was deposited, forming what is known as boulder clay, till, or glacial drift. Much of this material was overridden by the glacier and formed a ground moraine, but much was carried with it. Where the rate of melting at the front of the glacier just about

equaled, for a long period, the forward movement, the accumulated deposit formed a morainal ridge, known as the terminal moraine. In the final recession or melting, the drift material was irregularly deposited over the intermorainal tracts, giving a slightly rolling topography to the area. In some cases, superglacial and subglacial streams played a part in the deposition of material, the former giving rise to gravel mounds known as "kames," and the latter to gravel ridges called "eskers." A good example of the kame may be seen in Sections 25 and 30, about three miles southeast of Aroma, in the gravel mound known as Mount Langman.

The action of the ice sheets as they passed over the county was generally to destroy the then existing topography by wearing down any hills and filling the valleys with the debris, thus producing a region more nearly level than had previously existed. In this way hilly areas which would have been unsuited to agriculture became well adapted for the very best form of agriculture.

The amount of material transported by these glaciers was enormous. The deposit in the western, southern, and northeastern parts of the county averages 100 feet in thickness, according to Leverett. That in the northeastern part is largely intermorainal; it is deep in some places but very irregular.

The late Wisconsin glacier pushed over the present site of Lake Michigan and extended nearly to the southeastern corner of Iroquois county. As it receded it built up the very extensive Valparaiso moranic system, somewhat concentric with the lake, touching the extreme northern and northeastern parts of the county. During the recession of the glacier the flood waters were forced to find an outlet to the south. Part of these waters passed thru the Desplaines to the Illinois river, while an immense flood came down from what is now Indiana into the region of the Kankakee river, and found its way to the Illinois. This flood carried away much of the finer material that had been deposited by the glacier, leaving large quantities of sand and gravel which were later covered by finer material. Part of this water broke thru a moraine in the northern part of Iroquois county, flooding a large area and ultimately finding its way to the Illinois river thru the Vermilion. Large deposits of sand were made in this flooded area, which were subsequently reworked by the wind and now comprize the sand dunes. The bed of this old lake was but poorly drained, and it now forms what is known as the Kankakee swamp.

PHYSIOGRAPHY AND DRAINAGE

Kankakee county lies in the drainage basin of the Kankakee river. This stream has not had time since the glaciers to cut a deep channel, and so the drainage over large parts of the county is poor. This is especially true of the southeastern and northwestern parts and of the swamp region, generally; and even in the southwestern and northeastern, or morainal, parts there are poorly drained sloughs that are usually in permanent pasture. The amount of swamp land in the county at the time it was settled was very large. Old settlers frequently speak of the water formerly being deep enough to swim a horse in regions that have since been drained and are now used for grain crops, meadow, or pasture. Large areas need still more drainage before they can be brought under the best cultivation.

The altitude of the county averages not far from 650 feet. The highest point is 750 feet above sea level, while the lowest, where the Kankakee river leaves the county, is about 550 feet. Following are the altitudes of some of the railroad stations: Aroma, 616; Bonfield, 632; Buckingham, 655; Clarke City, 592; Essex, 588; Exline, 630; Goodrich, 634; Grant Park, 697; Greenwich, 646; Hersher, 661; Hopkins Park, 676; Illinoi, 631; Irwin, 665; Kankakee, 631; Manteno, 694; Momence, 632; Otto, 632; St. Anne, 657; Sollitt, 710; Union Hill, 620; Tucker, 698.

The Kankakee river at the east line of Kankakee county has an altitude of 620 feet and at Aroma (Waldron P. O.), 600 feet. East of Aroma it flows in a valley that is usually less than fifteen feet below the general upland. This shallow basin furnishes very poor drainage for the flat region somewhat remote from the river in the eastern part of the county. Many dredge ditches have been made, but the small amount of fall and the mobile character of the sand are serious difficulties. Somewhat similar conditions prevail in the northwestern part of the county, where considerable areas of undrained land still exist. Very frequently the drainage is obstructed by sand ridges, or sand dunes, making it very difficult to get a proper outlet. The upland in the northeastern part of the county contains a large number of streams flowing southward into the Kankakee river. Many of these are "sloughs," in need of dredging.

SOIL MATERIAL AND SOIL TYPES

The northeastern, north-central, and extreme southwestern parts of Kankakee county are covered to a considerable depth with glacial drift overlain with a finer deposit of loessial or wind-blown material from which the soil has been formed. This layer of finer material varies in thickness from one to three feet and gives to these parts of the county a much finer soil than that derived directly from glacial material. The low areas of these regions have received fine material that has been washed in from the higher parts, and this has resulted in the formation of a soil somewhat different from that on the rolling areas. In some small places the loess has been removed by erosion and the soil is formed from glacial drift.

The less extreme southwestern and southern parts of the county are covered with glacial drift. Much of this area was once covered by the old lake that existed there. The waters of the lake deposited considerable quantities of sand over this area, and this sand, mixed with fine loessial material, now constitutes the soil. In many cases the wind carried the sand to higher places along the shore than were reached by the water.

The large area of the swamp between the glacial regions, as indicated on the map, consists of soils that have been derived from lake deposits or largely modified by the lake and the currents which flowed thru it. Large quantities of the finer glacial material have been washed away from this region, leaving the coarser material, which in some cases is still exposed. Boulders are very common over some parts, so much so that cultivation is very difficult, and in a few small areas impossible until the boulders are removed. In the western part of the county, these boulders and pebbles have been covered with fine material to a depth of from sixteen inches to several feet.

In many parts of this old lake bed, large quantities of sand have been depos-

ited and later reworked by the wind, forming extensive areas of sand dunes, which completely bury the coarser material. In some places, organic matter has accumulated in quantities sufficient to produce different types of peat or peaty loam. These areas are not confined entirely to the lower, more poorly drained areas, but frequently occur on the upland, especially in the northeastern part of the county. Very peculiar areas of peat, ten to fifteen rods wide, are found at the base of the bluff on the north side of this old lake, extending about five miles northeastward from Momence. The conditions favorable to the formation of peat have been produced by the springs and seepage from the bluff.

TABLE 1.—SOIL TYPES OF KANKAKEE COUNTY, ILLINOIS.

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 28)			
926, 1026, 1126, 1226	Brown silt loam	239.36	153 191	35.74
1226.5	Brown silt loam on rock	1.98	1 267	.28
920, 1020, 1120, 1220	Black clay loam	24.21	15 494	3.61
1121, 1221	Drab clay loam	6.93	4 435	1.03
960, 1060, 1160, 1260	Brown sandy loam	87.89	56 250	13.12
1160.5	Brown sandy loam on rock	.27	173	.04
1090	Gravelly loam	.09	57	.01
	(b) Upland Timber Soils (page 32)			
1234	Yellow-gray silt loam	7.82	5 005	1.16
1235	Yellow silt loam	.92	589	.14
1064	Yellow-gray sandy loam	.83	531	.12
	(c) Terrace Soils (page 39)			
1520	Black clay loam	5.68	3 635	.85
1527	Brown silt loam over gravel	7.95	5 088	1.18
1528	Brown-gray silt loam on tight clay	.14	90	.02
1560	Brown sandy loam	211.83	135 571	31.63
1560.5	Brown sandy loam on rock	15.16	9 702	2.26
1564	Yellow-gray sandy loam	.51	326	.08
1581	Dune sand	36.69	23 482	5.48
	(d) Late Swamp and Bottom-Land Soils (page 47)			
1401	Deep peat	2.73	1 748	.41
1402	Medium peat on clay	1.06	678	.16
1402.2	Medium peat on sand	1.71	1 094	.26
1410.2	Peaty loam on sand	6.15	3 936	.92
1410.3	Peaty loam on rock	1.39	890	.21
1454	Mixed loam	3.84	2 457	.58
1413	Clayey muck	.14	90	.002
	(e) Miscellaneous			
99	Rock outcrop	.09	58	.002
	Water	4.76	3 046	.71
	Total	670.13	428 883	100.00

The soils of Kankakee county are divided into the following four classes:

(a) Upland prairie soils, rich in organic matter. These were covered originally with prairie grasses, the partly decayed roots of which have been the source of the organic matter.

(b) Upland timber soils, including a large part of the upland that was formerly covered with forests.

(c) Terrace soils, or, more properly, those soils which occupy the gravel and sand outwash plain produced by the old lake.

(d) Late swamp and bottom-land soils, which include the overflow lands or flood plains of streams and the very poorly drained lowlands where peats, peaty loams, and mucks have been formed.

(e) Miscellaneous.

Table 1 shows the area of each type of soil in Kankakee county in square miles and in acres, and its percentage of the total area. The accompanying maps show the location and boundary lines of the various types, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN KANKAKEE COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of a soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants

(legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

In Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type in Kankakee county—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize it.

The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common upland soil of Kankakee county, the brown silt loam prairie, does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for eleven rotations (44 years), and some other extensive soils in the county are not markedly different.

With respect to phosphorus, the condition differs only in degree, this most important upland soil of the county containing no more of that element than would be required for sixteen crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium in this common soil type is sufficient for 30 centuries if only the grain is sold, or for 500 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,500 and 600 years for magnesium, and about 9,000 and 200 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and as explained in the Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the most prevalent type in the county certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

The variation among the different types of soil in Kankakee county with respect to their content of important plant-food elements is also very marked. The deep peat contains in the plowed soil of an acre thirty times as much nitrogen as the dune sand, and about five times as much nitrogen but only one-fifth as much potassium as the brown silt loam. The total supply of phosphorus in

TABLE 2.—FERTILITY IN THE SOILS OF KANKAKEE COUNTY, ILLINOIS
Average pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
926, 1026, 1126, 1226	Brown silt loam	66 260	5 680	1 210	37 780	9 780	9 800		90
1226.5	Brown silt loam on rock	41 820	3 640	840	32 720	7 600	8 580		60
1020, 1120, 1220	Black clay loam	77 410	6 890	1 500	39 110	13 820	16 000	Seldom	40
1121, 1221	Drab clay loam	88 370	8 150	1 620	38 290	13 720	17 540		20
960, 1060, 1160, 1260	Brown sandy loam	81 420	6 220	1 140	33 800	8 840	12 500	Seldom	40
1160.5	Brown sandy loam on rock	54 520	4 660	1 000	33 980	7 680	11 900		20
1090	Gravelly loam	88 860	8 920	1 760	37 960	37 520	65 040	265 640	
	Upland Timber Soils								
1234	Yellow-gray silt loam	31 250	2 710	810	37 590	7 110	6 940		90
1235	Yellow silt loam	24 120	2 040	720	41 600	7 860	6 080		40
1064	Yellow-gray sandy loam	29 300	1 940	560	28 400	5 620	9 160		60
	Terrace Soils								
1520	Black clay loam	107 360	8 280	2 200	38 380	10 680	16 860		60
1527	Brown silt loam over gravel	107 300	9 160	1 400	33 360	11 660	18 140		40
1528	Brown-gray silt loam on tight clay	74 560	6 540	1 780	31 620	9 140	5 440		740
1560	Brown sandy loam	58 360	5 550	990	24 100	5 290	10 120		90
1560.5	Brown sandy loam on rock	92 690	7 770	1 200	26 870	8 890	14 140	Seldom	Often
1564	Yellow-gray sandy loam	24 940	1 700	720	19 940	3 380	4 800		460
1581	Dune sand	11 100	880	600	26 820	3 160	6 030		30
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1]	291 030	26 710	1 460	6 830	3 770	24 430	Often	Often
1402	Medium peat on clay[1]	216 900	19 970	1 570	10 060	5 230	17 750		190
1402.2	Medium peat on sand[1]	221 970	18 810	750	9 870	2 430	20 170	4 420	
1410.2	Peaty loam on sand	94 670	8 670	1 330	20 770	4 930	19 840	Seldom	Often
1410.3	Peaty loam on rock	134 400	11 120	1 760	19 820	6 860	17 280		20
1454	Mixed loam	112 600	9 020	1 560	42 220	13 200	17 340	11 420	
1413	Clayey muck	262 660	27 900	2 080	32 700	12 600	25 540		20

[1]Amounts reported are from 1 million pounds of deep peat and medium peat.

the surface soil varies from 560 pounds per acre on the upland and 720 pounds on the terrace, in the yellow-gray sandy loams, to 2,200 pounds in the black clay loam terrace. The magnesium and calcium vary from about 3,000 or 4,000 pounds in the lighter terrace soils to 15,000 or 20,000 pounds in some other types. Some types contain an abundance of limestone, while others are practically neutral or slightly acid, and still others, such as the brown-gray silt loam on tight clay and the yellow-gray sandy loam (both terrace soils) and all upland timber soils, are distinctly acid in the surface, more strongly acid in the subsurface, and sometimes devoid of limestone even in the subsoil. More than 90 percent of the soils of the county contain no limestone in the surface or subsurface to a depth of 20 inches.

With an inexhaustible supply of nitrogen in the air, and with 38,000 pounds of potassium in the most common prairie soil, the economic loss in farming such land with some acidity and with only 1,200 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by the proper use of limestone and phosphorus in rational farm systems, without change of seed or season and with very little more work than is now devoted to the fields. Fortunately, some definite field experiments have already been conducted on this most extensive type of soil on the University experiment fields in nearby counties, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county. Before considering in detail the individual soil types, it seems advisable to study some of the results already obtained where definite systems of soil improvement have been tried out on some of these experiment fields in different parts of central Illinois.

RESULTS OF FIELD EXPERIMENTS AT URBANA

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901. From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed. The average yields are recorded in Table 3.

A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields of clover in 1903 were taken by carefully weighing the yields from small representative areas; but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 3 in computing yields and values.) The average yields of hay shown in the table represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Le), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the

regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently as many tons of manure have been applied as there have been tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone was applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained on the following page.

Phosphorus (P) has been applied on Plots 6 to 9 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one-half of each phosphorus plot has received 600 pounds of rock phosphate in the place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this "extra heavy" treatment was not begun until 1906, only the usual lime, phosphorus, and potassium having been applied in previous years. The purpose in making these heavy applications is to try to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the various plots were treated the same as the corresponding plots in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation, wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then to be brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 4.)

From 1911 to 1915 soybeans were substituted four years because of clover failure; accordingly four-fifths of the soybeans and one-fifth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912 the field was plowed and reseeded. The average yield reported for alfalfa in Table 4 is one-fifth of the combined crops of 1912, 1913, 1914, and 1915.

The "higher prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "lower prices" are 70 percent of these values, or 70 cents for wheat and soybeans, 35 cents for corn, 28 cents for oats, $7 for clover seed, and $7 a ton for hay. The two sets of values are used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they

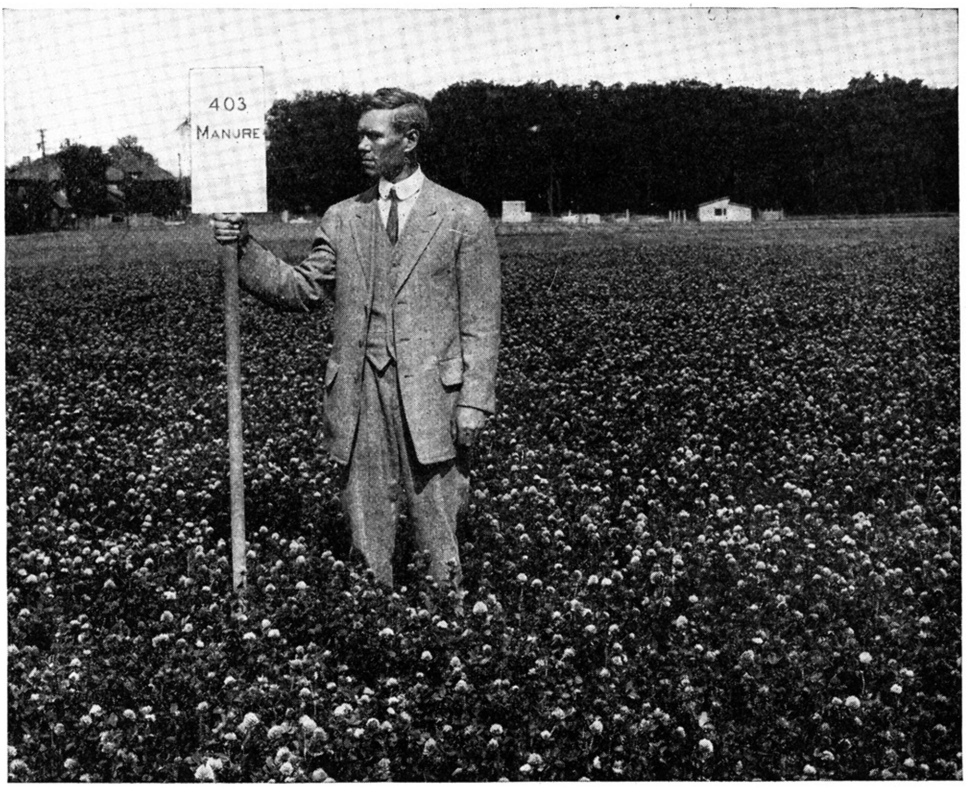

PLATE 1.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing and marketing. Measured by the average Illinois prices for the past ten years these lower values are high enough for farm crops standing in the field ready for the harvest.

The cost of limestone delivered at a farmer's railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $25 to $30 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains, ton for ton, but in less readily available form, usually costs the farmer from $6.50 to $7.50 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, commonly costs from $15 to $17 per ton delivered in carload lots in central Illinois.) Under normal condition potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

To these cash investments must be added the expense of hauling and spreading the materials. This will vary with the distance from the farm to the railroad station, with the character of the roads, and with the farm force and the immediate requirements of other lines of farm work. It is the part of wisdom to order such materials in advance to be shipped when specified, so that they may be

PLATE 2.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

received and applied when other farm work is not too pressing and, if possible, when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

At the lower prices for produce, manure (6 tons per acre) was worth $1.05 a ton as an average for the first three years during which it was applied (1905 to 1907). For the next rotation the average application of 10.21 tons per acre on Plot 3 was worth $10.09, or 99 cents a ton. During the next four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11.35 tons per acre, worth $6.42, or 57 cents a ton, as measured by its effect on the wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth 84 cents a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last rotation period moisture has been the limiting factor to such an extent as probably to lessen the effect of the manure.

TABLE 3.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905-1907						
	Soil treatment	Corn, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treatment	Corn, bu.	Oats, bu.	Clover, tons	Value of 3 crops		Soil treatment
					Lower prices	Higher prices					Lower prices	Higher prices	
1	0........	75.4	48.8	.49	$43.48	$62.12	0......	71.5	46.6	2.07	$52.56	$75.09	0......
2	Le......	77.4	45.1	.44	42.80	61.14	Le.....	68.5	52.0	1.83	51.34	73.35	R......
3	0........	75.3	50.4	.41	43.33	61.91	M......	80.5	54.8	2.19	58.84	84.07	M......
4	LeL.....	78.4	47.3	.42	43.62	62.32	LeL....	72.3	58.6	1.98	55.57	79.39	RL.....
5	L.......	80.8	58.2	.44	47.66	68.08	ML....	84.8	59.8	2.46	63.64	90.92	ML....
6	LeLP....	88.0	52.5	.50	49.00	70.00	LeLP..	90.4	70.7	2.69	70.26	100.38	RLP...
7	LP......	88.8	56.6	.98	53.79	76.84	MLP...	93.2	71.6	3.47	76.96	109.94	MLP...
8	LeLPK..	90.1	48.3	.64	49.53	70.77	LeLPK.	93.8	71.7	3.06	74.32	106.18	RLPK..
9	LPK....	90.5	54.3	1.34	56.26	80.37	MLPK.	95.6	66.9	3.73	78.30	111.86	MLPK.
10	LPK....	86.5	53.2	1.23	53.78	76.83	MxLPx.	90.1	62.9	2.86	69.17	98.81	MxLPx.

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications o
residues (corn stalks, straw of wheat and oats, and all legumes except seed).

TABLE 4.—YIELDS PER ACRE, FIVE-YEAR AVERAGES, 1911-15: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans–4, tons (bu.)	Clover–1, tons[1] (bu.)	Alfalfa, tons	Value of 5 crops	
								Lower prices	Higher prices
1	0........	22.2	53.9	46.3	1.60	2.50	2.27	$75.72	$108.17
2	R.......	23.5	56.4	47.8	(21.3)	(.74)	1.85	75.48	107.84
3	M.......	24.8	63.6	54.6	1.68	2.20	1.68	79.16	113.08
4	RL......	25.0	59.2	49.7	(20.7)	(1.03)	1.72	77.21	110.30
5	ML......	28.1	63.4	57.3	1.72	2.81	2.25	87.22	124.60
6	RLP.....	39.1	66.0	64.3	(22.6)	(2.48)	3.28	107.56	153.66
7	MLP....	38.3	67.6	64.9	1.92	4.04	3.25	107.80	154.00
8	RLPK...	38.2	63.7	64.5	(24.2)	(1.41)	3.22	105.17	150.23
9	MLPK	37.4	64.6	69.3	2.09	3.91	3.31	108.54	155.06
10	MxLPx	42.9	61.0	72.5	2.19	4.24	3.45	114.03	162.90

[1] The second cutting of clover hay was not included in reporting this crop in Soil Reports 9, 10, and 12.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plot 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5 respectively.

As a general average, the plots receiving limestone have produced $1.17 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all of the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, these increases varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.06 on five acres (Plot 5) as an average of the last five years. The need of limestone for best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in bone meal produced increases valued at $1.92 per acre per annum for the first three years and at $4.67 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $5.12 for the third rotation and $5.09 for the last five years, 1911 to 1915. The annual expense per acre for phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for rock phosphate at $7 a ton.

Potassium, applied at an estimated cost of $2.50 an acre a year, seemed to produce slight increases, as an average, during the first and second rotations; but subsequently those increases have been slightly more than lost in reduced average yields, the net result to date being an average loss of $2.43 per acre per annum or a loss of 97 cents for every dollar invested in potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as an average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,200 pounds of phosphorus and more than 36,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last five years is about $75. Where limestone and phosphorus have

PLATE 3.—CLOVER ON URBANA FIELD, SOUTH FARM
CROP RESIDUES PLOWED UNDER

been used together with organic manures (either crop residues or farm manure), the corresponding value is $107. Thus 200 acres of the properly treated land would produce almost as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk, with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. Wheat, however, has as an average yielded best on this plot. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

As an average of the results secured during the twelve years 1903 to 1914, on the University South Farm where fine-ground raw rock phosphate is applied at the rate of 500 pounds per acre per annum on the typical brown silt loam prairie soil, the return for each ton of phosphate[1] used has been $13.57 on Series 100 and $12.07 on Series 200, with the "lower prices" allowed for produce, the rotation being wheat, corn, oats, and clover (or soybeans). This gives an average

[1] During the first four years Series 100 received only 1,500 pounds per acre of phosphate, and both series received also ½ ton per acre of limestone, the effect of which probably would be slight, as may be judged from the data secured later and reported herein.

PLATE 4.—CLOVER ON URBANA FIELD, SOUTH FARM
FINE-GROUND ROCK PHOSPHATE PLOWED UNDER WITH CROP RESIDUES

return of $12.82 for each ton of phosphate applied. Averages for each rotation period show the following values for the increase per ton of phosphate used:

	Lower prices	Higher prices
First rotation, 1903 to 1906	$ 8.26	$11.80
Second rotation, 1907 to 1910	11.33	16.19
Third rotation, 1911 to 1914	18.88	26.97

Thus the rock phosphate paid back more than its cost during the first rotation, more than 1½ times its cost during the second rotation, and more than 2½ times its cost during the third rotation period.

One ton of fine-ground rock phosphate costs about the same as 500 pounds of steamed bone meal. Altho in less readily available form, the rock phosphate contains as much phosphorus, ton for ton, as the bone meal; and, when equal money values are applied in connection with liberal amounts of decaying organic matter, the natural rock may soon give as good results as the bone—and, by supplying about four times as much phosphorus, the rock provides for greater durability.

The results just given represent averages covering the residue system and the live-stock system, both of which are represented in this crop rotation on the South Farm.

TABLE 5.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SE
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1903	Corn 1904	Oats 1905	Wheat 1906	Clover 1907	Corn 1908	Oats 1909	Clover 1910	Wheat[2] 1911	Corn 1912	Oats 1913	Soybeans 1914	Value 1st fo years	
		Bushels or tons per acre[1]												Lower prices	High pric
163	RP......	45.1	54.1	57.5	39.8	(.83)	72.0	45.4	(.60)	46.85	74.9	26.8	(16.6)	$78.68	$112
166	RP......	43.8	49.3	60.9	36.5	(1.00)	74.9	40.8	(1.30)	53.40	79.5	24.6	(17.5)	75.19	107
169	R........	42.7	39.5	49.3	28.4	(.90)	65.0	39.9	(1.70)	36.71	67.9	19.1	(15.3)	62.45	89
170	M........	41.8	38.7	52.2	26.2	2.56	69.6	40.1	2.87	35.85	76.7	22.5	1.09	61.13	87
173	MP.....	35.4	53.3	54.6	32.8	3.65	78.4	39.8	4.23	52.65	83.7	29.6	1.45	69.29	98
176	MP.....	39.3	58.1	61.9	38.8	3.74	79.5	40.0	4.23	51.03	85.6	32.1	1.52	78.58	112
163	RLP....	....	....	....	....	....	....	....	....	49.9	87.0	28.2	(18.1)	....	....
166	RLP....	....	....	....	....	....	....	....	....	53.6	81.4	26.8	(18.0)	....	....
169	R........	....	....	....	....	....	....	....	....	33.8	62.7	17.0	(15.2)	....	....
170	M........	....	....	....	....	....	....	....	....	32.4	74.4	22.0	1.09	....	....
173	MLP....	....	....	....	....	....	....	....	....	51.3	85.7	28.0	1.37	....	....
176	MLP....	....	....	....	....	....	....	....	....	51.0	85.6	30.9	1.47	....	....

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1911 the acre-yields are based on half-plots, limestone having been applied to one half of each of the p

TABLE 6.—YIELDS AND VALUES IN SOIL EXPERIMENTS, UNIVERSITY SOUTH FARM: SER
COMMON BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Oats 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Oats 1908	Wheat 1909	Wheat[2] 1910	Corn 1911	Oats 1912	Soybeans 1913	Wheat 1914	Value 1st fo years	
		Bushels or tons per acre[1]												Lower prices	Hig pric
263	RP.....	24.7	25.7	32.1	.82	65.3	31.3	42.5	43.7	52.3	72.9	(13.7)	30.61	$42.32	$60.
266	RP.....	23.1	24.5	29.3	.80	59.7	26.7	40.7	32.3	50.2	75.7	(12.3)	33.86	39.43	56.
269	R.......	26.8	22.5	26.8	.86	57.9	31.5	39.4	25.3	35.5	61.9	(10.7)	16.11	38.58	55.
270	M......	22.0	21.5	24.0	.82	55.3	30.0	37.1	28.7	43.1	67.8	.84	17.40	34.72	49.
273	MP.....	23.9	25.0	27.8	.77	62.5	29.5	43.4	43.7	38.6	69.4	1.17	37.16	38.54	55.
276	MP	16.1	25.3	30.7	.68	58.0	27.9	44.1	38.2	48.0	68.6	1.34	41.98	37.84	54.
263	RLP....	.....	.....	.....	.....	.....	.....	.....	49.0	50.3	78.9	(13.2)	40.36	.....	.....
266	RLP....	.....	.....	.....	.....	.....	.....	.....	45.2	47.1	78.7	(10.3)	36.01	.....	.....
269	R.......	.....	.....	.....	.....	.....	.....	.....	35.3	45.3	68.4	(10.5)	20.71	.....	.....
270	M......	.....	.....	.....	.....	.....	.....	.....	33.3	45.2	73.2	1.12	20.06	.....	.....
273	MLP....	.....	.....	.....	.....	.....	.....	.....	46.2	53.7	69.0	1.27	46.23	.....	.....
279	MLP....	.....	.....	.....	.....	.....	.....	.....	39.5	50.6	69.5	1.24	48.98	.....	.....

[1]For legumes, figures in parentheses indicate bushels of seed; the others, tons of hay.
[2]From 1910 the acre-yields are based on half-plots, limestone having been applied to one half of each of the p

Ground limestone at the rate of 8 tons per acre was applied to the east half of these series of plots (excepting the check plots, which receive only residues or manure), beginning in 1910 on Series 200 and in 1911 on Series 100. Subsequent applications are made of 2 tons per acre each four years, beginning in 1914 on Series 200 and in 1915 on Series 100. As an average of the results from both series, the crop values were increased during the third rotation, 1911-1914, as follows:

	Residue System		Live-Stock System	
	Lower prices	Higher prices	Lower prices	Higher prices
Gain for phosphate............	$18.80	$26.86	$18.96	$27.09
Gain for limestone.............	2.31	3.30	2.55	3.64

Detailed records of these investigations are given in Tables 5 and 6, the data being reported by half-plots after 1910-1911. (Series 300 and 400, which are also used in this rotation, are located in part upon black clay loam and a heavy phase of brown silt loam. See discussion under "Black Clay Loam," p. 30.)

Results of Experiments on Sibley Field

Table 7 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen *and* phosphorus increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910 the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910 and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results. In 1913, wheat averaged 6.6 bushels without nitrogen or phosphorus (Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
		Bushels per acre											
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro. phos	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, pitro., potas	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0

Increase: Bushels per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
For nitrogen	.0	.3	2.8	1.1	2.5	9.2	11.6	–9.8	–5.0	.2	–60.3	11.5
For phosphorus	1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
For potassium	–4.0	–4.1	–.3	–1.5	–1.7	–4.0	–2.5	–5.6	.2	–.6	–2.5	.7
For nitro., phos. over phos	–4.0	6.8	–4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	–50.1	14.0
For phos., nitro. over nitro	–2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
For potas., nitro., phos. over nitro., phos	1.4	–3.2	–5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0	–.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops: Lower prices	Higher prices
101	None	$172.89	$246.98
102	Lime	186.51	266.45
103	Lime, nitrogen	177.44	253.49
104	Lime, phosphorus	217.78	311.11
105	Lime, potassium	167.32	239.03
106	Lime, nitrogen, phosphorus	246.91	352.73
107	Lime, nitrogen, potassium	198.16	283.08
108	Lime, phosphorus, potassium	204.90	292.71
109	Lime, nitrogen, phosphorus, potassium	257.91	368.45
110	Nitrogen, phosphorus, potassium	242.47	346.38

Value of Increase per Acre in Twelve Years

	Lower prices	Higher prices
For nitrogen	–$ 9.07	–$12.96
For phosphorus	31.27	44.66
For *nitrogen* and phosphorus over phosphorus	29.13	41.62
For *phosphorus* and nitrogen over nitrogen	69.47	99.24
For *potassium*, nitrogen and phosphorus over nitrogen and phosphorus	11.00	15.72

In the lower part of Table 7 are shown the total values per acre of the twelve crops from each of the ten different plots, the amounts varying from $167.32 to $257.91, with corn valued at 35 cents a bushel, oats at 28 cents, and wheat at 70 cents. Phosphorus without nitrogen has produced $31.27 in addition to the increase by lime, but with nitrogen it has produced $69.47 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $14.53, or $1.21 an acre a year. The increase on these plots is practically the same as on the field at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 8 and 9, giving all results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the thirteen years' work tell much the same story as those from the Sibley field. The rotations have differed since 1905 by the use of clover and the discontinuing of the use of commercial nitrogen—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, has produced an even larger increase ($99.85) than has been produced by phosphorus and nitrogen over nitrogen on the Sibley field ($69.47).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101 occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 8 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $7.02 an acre. This is $4.52 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots on the Bloomington field, 180 pounds per acre of phosphorus, as an average, has been removed in the thirteen crops. This is equal to 15 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown for eighty years, they would require as much phosphorus as now constitutes the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909
		Bushels or tons per acr							
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6
103	Lime, crop residues[2]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3
106	Lime, residues,[2] phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5
107	Lime, residues,[2] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5
109	Lime, residues,[2] phosphorus, potassium	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3

Increase: Bushels or Tons per Acre

	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909
For residues	–1.9	–.8	9.0	1.7	–.12	1.2	1.6	–4.2
For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2
For potassium	.7	–3.9	1.7	4.4	–.07	1.0	.9	–8.3
For residues, phosphorus over phosphorus	2.2	4.6	12.6	11.7	–1.65	–3.2	–1.7	8.7
For phosphorus, residues over residues	8.8	18.1	15.5	20.4	–.46	14.6	8.9	23.1
For potassium, residues, phosphorus over res., phos	8.8	3.3	5.2	1.0	.00	9.5	12.3	–8.3

[1]For clover the figures indicate tons per acre, except where in parentheses, in which case they indicate bushe
[2]Commercial nitrogen was used from 1902 to 1905.
[3]Clover smothered by previous wheat crop.

year. Where no phosphorus has been applied, the crops have removed only 120 pounds of phosphorus in the thirteen years, which is equivalent to only 10 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1914, as an average of all plots where it has been used, has amounted to 325 pounds per acre and has cost $32.50.[1] This has paid back $97.20, as an average

TABLE 9.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, BLOOMINGTON FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices	Higher prices
101	None	$186.83	$266.90
102	Lime	186.76	266.80
103	Lime, residues	193.83	276.90
104	Lime, phosphorus	286.61	409.45
105	Lime, potassium	190.53	272.19
106	Lime, residues, phosphorus	285.03	407.19
107	Lime, residues, potassium	191.10	273.00
108	Lime, phosphorus, potassium	294.91	421.31
109	Lime, residues, phosphorus, potassium	284.47	406.39
110	Residues, phosphorus, potassium	259.10	370.15

Value of Increase per Acre in Thirteen Years

	Lower prices	Higher prices
For residues	$ 7.07	$10.10
For phosphorus	99.85	142.65
For *residues* and phosphorus over phosphorus	-1.58	-2.26
For *phosphorus* and residues over residues	91.20	130.29
For *potassium*, residues, and phosphorus over residues and phosphorus	-.56	-.80

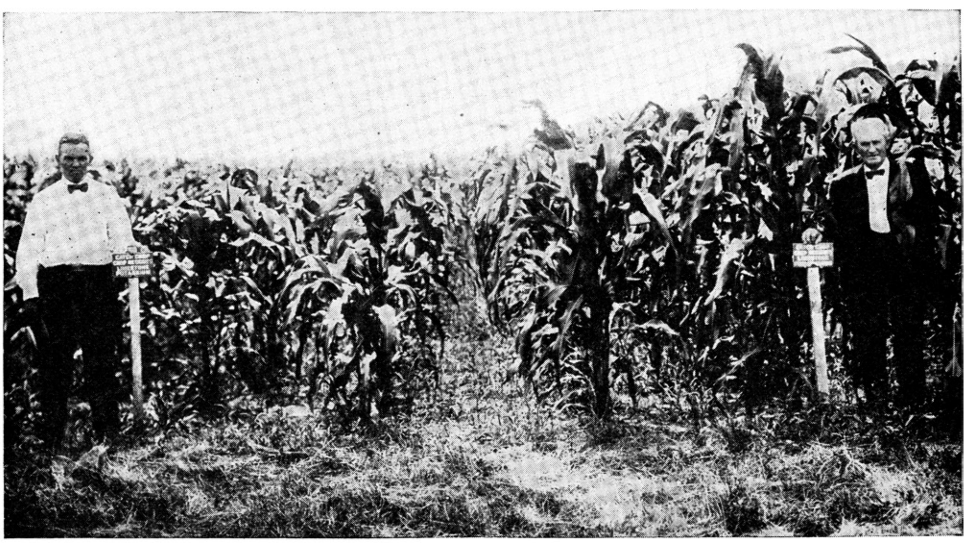

PLATE 5.—CORN IN 1912 ON BLOOMINGTON FIELD
ON LEFT, RESIDUES, LIME, AND POTASSIUM: YIELD, 58.9 BUSHELS
ON RIGHT, RESIDUES, LIME, AND PHOSPHORUS: YIELD, 86.1 BUSHELS

[1] This is based on $25 a ton for steamed bone meal, but in recent years the price has been advanced, as a rule, to nearly $30.

of four trials, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $2.20 per acre in the thirteen years, or less than 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops? (See Table 2; also Table A in the Appendix.)

Nitrogen was applied to the residue plots of this field (except Plot 110), in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910 clover, except the seed, was plowed under on the five residue plots. Straw and corn stalks have been returned to these plots, beginning with 1908. The effect of returning these residues to the soil has been appreciable since 1908 (an average increase on Plots 106 and 109 of 5.5 bushels of oats, 4.5 bushels of wheat, and 5.4 bushels of corn) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the thirteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil, for the roots and stubble of clover contain no more nitrogen than the

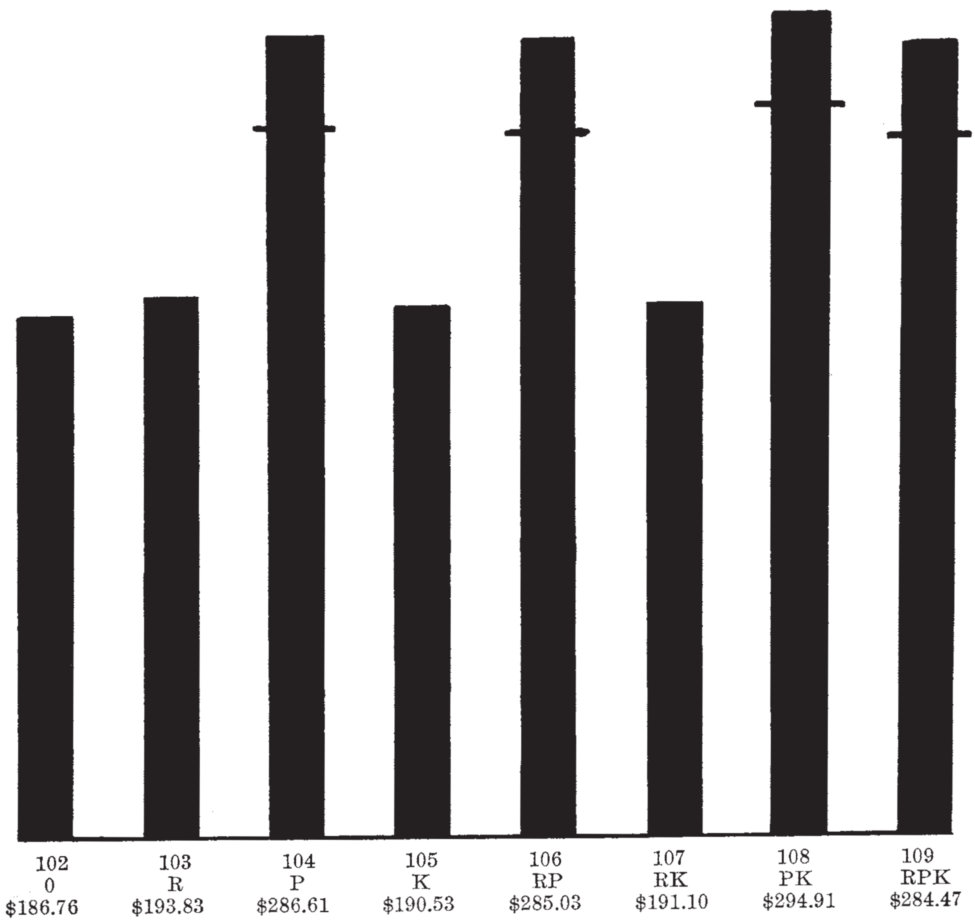

PLATE 6.—CROP VALUES FOR THIRTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD
(R=residues; P=phosphorus; K=potassium, or kalium)

entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 6 shows graphically the relative values of the thirteen crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in thirteen years only $1.58 below that from Plot 104 (LP). (See also table on last page of cover.)

RESULTS OF EXPERIMENTS ON JOLIET FIELD

In 1914 experimental work was begun on the Joliet experiment field located about three miles northwest of Joliet on the line of the Aurora and Joliet interurban railway. This field occupies thirty-two acres of brown silt loam prairie of the late Wisconsin glaciation.

Ground limestone, at the rate of 4 tons per acre, was the only material applied for the 1914 crops. For 1915 crop residues (corn stalks and straw or chaff from wheat, oats, soybeans, and clover) were turned under, raw rock phosphate and kainit were applied to some plots, as indicated in Table 11, and farm manure was added to Plots 502, 503, and 504 in proportion to the total crop yields of 1914 on the corresponding plots of all series. The amounts of phosphate and kainit applied in pounds per acre were as follows:

Series	Phosphate	Kainit
300...........	500	200
400...........	1,000	400
500...........	1,500	600
100...........	2,000	800
200...........	2,500	1,000
600...........	3,000	1,200

Subsequent applications are to be made at the rate of 500 pounds of phosphate and 200 of kainit per acre per annum, but they are to be put on in larger amounts once during the rotation, on a different series each year, beginning with Series 300 for 1916.

In Tables 10 and 11 are recorded in detail the crop yields secured in 1914 and 1915, with summaries of crop values at the two prices. Of course no conclusions should be drawn from the results of the first year or two of such experiments, but the data may be of some value if studied in connection with those from longer investigations.

If we count 1,000 pounds of ground limestone per acre as the average annual allowance for "maintenance," then the average increase for limestone for the two seasons shows a return of $2.98 per ton at the lower prices or of $4.26 per ton at the higher prices.

TABLE 10.—YIELDS PER ACRE IN SOIL EXPERIMENTS, JOLIET FIELD, 1914
BROWN SILT LOAM PRAIRIE; LATE WISCONSIN GLACIATION

Series		100	200	300	400	500	Value of 5 crops	
Plot	Treatment	Wheat, bu.	Clover, tons (bu.)	Oats, bu.	Corn, bu.	Soybeans tons (bu.)	Lower prices	Higher prices
1	0	16.5	2.00	60.9	44.7	1.24	$66.93	$ 95.61
2	0	19.3	2.05	60.2	46.9	1.40	70.93	101.33
3	L	20.9	1.97	59.8	52.4	1.51	74.07	105.82
4	L	21.5	2.02	59.5	50.2	1.28	72.38	103.40
5	0	18.2	1.91	50.2	42.3	1.15	63.02	90.03
6	0	19.9	(.42)	53.3	50.6	(11.9)	57.83	82.62
7	L	20.8	(1.00)	60.8	53.2	(13.3)	66.51	95.02
8	L	20.2	(.92)	59.1	51.0	(11.9)	63.31	90.44
9	L	22.0	(1.83)	68.8	53.1	(14.8)	76.42	109.17
10	0	17.4	(1.25)	52.5	45.1	(11.1)	59.19	84.55
Average with limestone[1]							$71.10	$101.57
Average without limestone[1]							62.70	89.57
Increase for limestone							$ 8.40	$ 12.00

[1] These computed results include weighted averages for the legume hay and seed.

TABLE 11.—YIELDS PER ACRE IN SOIL EXPERIMENTS, JOLIET FIELD, 1915
BROWN SILT LOAM PRAIRIE; LATE WISCONSIN GLACIATION

Series		100	200	300	400	500	600	Value of 6 crops	
Plot	Treatment	Soybeans, bu.	Wheat, bu.	Soybeans, bu.	Oats, bu.	Corn, bu.	Alfalfa, tons	Lower prices	Higher prices
1	0	14.4	9.8	10.6	72.5	28.6	1.79	$ 67.20	$ 96.00
2	M[1]	15.2	7.9	12.5	73.0	36.3	2.13	72.98	104.25
3	ML[1]	15.2	14.3	13.3	70.5	38.3	2.83	82.91	118.45
4	MLP[1]	16.8	20.3	14.8	75.0	47.7	3.73	100.13	143.05
5	0	15.2	10.6	13.9	67.7	28.5	2.18	71.98	102.83
6	R	14.0	15.6	13.0	62.8	32.4	2.57	76.73	109.62
7	RL	15.8	20.0	13.7	63.6	28.7	2.90	82.80	118.29
8	RLP	15.2	24.9	15.1	65.0	31.2	3.39	91.49	130.70
9	RLPK	16.3	30.4	15.0	72.0	43.4	3.56	103.46	147.80
10	0	15.1	25.2	12.8	63.1	27.1	1.90	77.62	110.89
Average increase for limestone								$ 8.00	$ 11.43
Average increase for phosphate								12.95	18.50
Increase for kainit								11.97	17.10

[1] Manure applied for corn only (Series 500).

While 200 pounds per acre of phosphate each year would be ample to maintain the natural supply in the soil, the plan is to provide for positive soil enrichment by applying 500 pounds a year for several rotations. Even at this rate, the average increase produced in 1915, per ton of phosphate, amounts to $8.63 at the lower prices for the crops, or to $12.33 at the higher prices. These values compare well with $8.26 and $11.80, the values of the increase per ton of phosphate during the first rotation on the University South Farm at Urbana. The corresponding returns in the third rotation at Urbana were $18.88 and $26.97.

Kainit is used, not for soil enrichment, but as a stimulant. Its temporary use may be profitable. If used at all, it should be with intelligence and with the thought of increasing the production of legume crops, crop residues, or farm manure, which when turned under not only liberate potassium from the soil and phosphorus from rock phosphate, but also provide the necessary nitrogen for soil enrichment and finally make the further use of kainit or other potash salt ineffective and unprofitable. The 200 pounds of kainit per acre for each year supplies only 20 pounds of potassium, while the plowed soil of an acre contains

37,780 pounds of the same element, and a hundred-bushel crop of corn (grain and stalks) requires 73 pounds. In contrast, it may be noted that 4 tons of phosphate (the amount to be applied per acre in 16 years) will about double the phosphorus content of the plowed soil.

A six-crop rotation is practiced on the Galesburg experiment field on the brown silt loam prairie of the upper Illinois glaciation. During the first three years the average returns were $2.65 for phosphate and $4.05 for potash salt used in addition to phosphate, but during the next six years the corresponding average returns were $7.31 for phosphate and $1 for potash. This was in a rational

TABLE 12.—FERTILITY IN THE SOILS OF KANKAKEE COUNTY, ILLINOIS
Average pounds per acre in 4 million pounds of subsurface soil (about 6⅔ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
926, 1026, 1126, 1226	Brown silt loam	54 600	5 150	1 580	82 820	22 700	15 700		500
1226.5	Brown silt loam on rock	52 880	5 160	1 480	65 080	23 320	20 120		40
1020, 1120, 1220	Black clay loam	55 890	5 610	2 100	80 250	28 840	27 280	Seldom	80
1121, 1221	Drab clay loam	49 650	4 890	2 070	83 090	29 550	25 120		50
960, 1060, 1160, 1260	Brown sandy loam	63 100	5 690	1 580	70 380	20 320	20 870	Seldom	240
1160.5	Brown sandy loam on rock	53 280	5 000	1 520	73 280	32 920	46 480	113 040	
1090	Gravelly loam	68 080	5 640	1 760	65 800	204 840	453 920	476 120	
	Upland Timber Soils								
1234	Yellow-gray silt loam	23 950	2 710	1 280	82 610	21 330	12 040		1 230
1235	Yellow silt loam	20 240	2 160	1 400	90 840	22 800	10 840		360
1064	Yellow-gray sandy loam	20 680	1 800	520	63 880	12 240	12 880		360
	Terrace Soils								
1520	Black clay loam	91 160	6 720	3 160	81 800	24 320	26 840		40
1527	Brown silt loam over gravel	65 080	5 680	1 840	73 960	23 560	24 640		40
1528	Brown-gray silt loam on tight clay	33 320	3 800	1 640	69 760	20 040	9 400		3 120
1560	Brown sandy loam	37 380	3 600	1 210	50 650	10 190	15 870		120
1560.5	Brown sandy loam on rock	62 610	5 470	1 730	54 630	40 360	60 950	Often	Seldom
1564	Yellow-gray sandy loam	17 120	1 280	1 000	40 000	7 240	7 240		3 920
1581	Dune sand	7 060	600	1 000	54 220	6 920	13 200		60
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1]	408 780	35 340	1 750	19 260	6 120	32 140		220
1402	Medium peat on clay[1]	267 720	24 220	2 040	24 720	11 040	28 420		60
1402.2	Medium peat on sand[1]	209 000	15 940	520	26 360	5 940	28 000	3 880	
1410.2	Peaty loam on sand	50 800	4 480	1 280	44 620	8 400	19 560	Often	Often
1410.3	Peaty loam on rock	98 120	7 280	1 920	46 080	17 760	25 240		40
1454	Mixed loam	88 080	8 800	1 680	83 560	20 960	22 280		40
1413	Clayey muck	512 000	50 360	3 160	60 880	23 480	54 520		40

[1]Amounts reported are from 2 million pounds of deep peat and medium peat.

system of farming which, of course, includes the use of home-grown organic matter.

THE SUBSURFACE AND SUBSOIL

In Tables 12 and 13 are recorded the amounts of plant food in the subsurface and the subsoil of the different types of soil in Kankakee county, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the most common prairie soil (brown silt loam) and the upland timber

TABLE 13.—FERTILITY IN THE SOILS OF KANKAKEE COUNTY, ILLINOIS
Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity present
	Upland Prairie Soils								
926, 1026, 1126, 1226	Brown silt loam....	30 760	3 560	2 130	151 330	74 260	78 100	265 660	Seldom
1020, 1120, 1220	Black clay loam....	25 980	2 940	2 840	130 520	71 960	89 180	Seldom	60
1121, 1221	Drab clay loam	23 800	2 920	2 900	140 660	52 780	42 660	59 490	Seldom
960, 1060, 1160, 1260	Brown sandy loam..	29 290	2 800	2 110	137 690	67 305	122 820	464 200	
1160.5	Brown sandy loam on rock..........	26 100	2 820	2 100	113 100	201 060	376 200	1 501 680	
1090	Gravelly loam	102 120	8 460	2 640	98 700	307 260	680 880	714 180	
	Upland Timber Soils								
1234	Yellow-gray silt loam	26 040	3 260	2 220	157 780	61 260	48 560	Often	Seldom
1235	Yellow silt loam ..	27 300	2 820	3 060	153 300	77 580	78 660	304 500	
1064	Yellow-gray sandy loam	17 520	1 860	1 500	134 700	96 360	104 340	390 180	
	Terrace Soils								
1520	Black clay loam....	42 840	3 660	7 860	128 340	34 320	33 600		60
1527	Brown silt loam over gravel	25 140	2 520	2 640	124 740	39 840	30 840	13 140	
1528	Brown-gray silt loam on tight clay.....	20 400	2 160	1 860	101 820	30 300	17 220		540
1560	Brown sandy loam...	18 370	1 600	1 110	77 890	16 680	22 090	Seldom	Often
1560.5	Brown sandy loam on rock	24 900	3 180	1 500	109 320	36 300	35 160	Often	
1564	Yellow-gray sandy loam	14 940	780	1 560	56 820	12 480	14 220		60
1581	Dune sand	10 590	900	1 500	81 330	10 380	19 800		90
	Late Swamp and Bottom-Land Soils								
1401	Deep peat[1].........	533 970	42 660	2 060	32 580	8 990	41 790		270
1402	Medium peat on clay	114 000	8 940	1 680	116 040	30 780	58 020	118 560	
1402.2	Medium peat on sand	119 460	6 300	1 140	64 800	66 000	574 620	1 472 940	
1410.2	Peaty loam on sand..	19 380	1 800	1 530	74 340	14 670	20 160		270
1454	Mixed loam	69 720	5 460	1 920	139 260	36 300	27 180		60
1413	Clayey muck	345 900	22 440	1 860	100 020	43 140	58 440		300

[1]Amounts reported are from 3 million pounds of deep peat.

soils are from slightly to strongly acid in the surface and subsurface and sometimes contain no limestone in the subsoil. This fact emphasizes the importance of having plenty of limestone in the surface soil to neutralize the acid moisture which rises from the lower strata by capillary action during times of partial drouth, which are critical periods in the life of such plants as clover. While the common brown silt loam prairie is usually slightly acid, the upland timber soils and the terrace soils are, as a rule, most distinctly in need of limestone. The timber soils are also more deficient in organic matter and nitrogen than the prairie soils and therefore more in need of growing clover.

INDIVIDUAL SOIL TYPES

(a) Upland Prairie Soils

The upland prairie soils of Kankakee county comprize 360.73 square miles, or 53.8 percent of the area of the county. They are usually quite dark in color owing to their large organic-matter content. They occupy the less rolling and comparatively level land.

Brown Silt Loam (926, 1026, 1126, 1226)

Brown silt loam is the most important as well as the most extensive type in Kankakee county, covering an area of 239.36 square miles (153,191 acres), or 35.74 percent of the area of the county. It occupies the less rolling upland, a large part of which needs artificial drainage. The presence of many shallow, basin-like depressions, or "kettle-holes," especially in the northeastern part of the county, makes complete drainage somewhat difficult. Many local areas of black clay loam or other types occur that are too small to be shown on the map. The brown silt loam of the late Wisconsin glaciation is shallower and lighter colored than that of the early Wisconsin. On the more rolling parts of the moraine, especially, small, light brown or even yellow patches occur quite frequently and are due to surface erosion. The top soil (the dark stratum) is frequently not over 8 or 10 inches thick on rolling land but it averages about 12 inches.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying in color from a light brown on the more rolling areas to dark brown or black on the more nearly level and poorly drained tracts. In physical condition it varies as it grades toward other types. The county contains large areas of sand; at one time not only the old swamp was filled with water, but the "sloughs" as well, and the washing of sand upon the shore and the movement of this by the wind resulted in the formation of areas of sandy loam or a sandy phase of what would otherwise be typical brown silt loam. This stratum normally contains 50 to 70 percent of the different grades of silt. As the type approaches black clay loam or the peats of the swampy areas, the clay content as well as the organic-matter content increases, the latter varying from 4.5 to 7.4 percent, with an average of 5.7 percent, or 57 tons per acre. The organic-matter content of the brown silt loam of the rolling areas of the late Wisconsin glaciation is less than the average, and of course the same is true of the nitrogen, which is a constituent part of the organic matter.

The natural subsurface varies from 2 to 12 inches in thickness. This varia-

tion is due to changing topography, the stratum becoming thinner where erosion has taken place to some extent. Less organic matter than the average has accumulated on these areas, also, and to a less depth, because of the less luxuriant growth of grass roots and their poorer preservation. In physical composition the subsurface varies the same as the surface soil, but it normally contains a slightly larger amount of clay and a smaller amount of organic matter, the latter averaging 2.4 percent. In color the subsurface varies from a dark brown or almost black to a yellow or yellowish drab. It becomes lighter with depth, passing into the subsoil at a depth of 9 to 18 inches.

The natural subsoil extends to an indefinite depth but is sampled to 40 inches. It varies from a yellow to a drabbish yellow, clayey material. Boulder clay usually begins at a depth of 16 to 28 inches, being deeper in the early Wisconsin glaciation than in the late Wisconsin. There are places, however, on the flatter areas in both glaciations where the subsoil to a depth of 40 inches does not reach the boulder clay, especially where material has washed in from the higher surrounding parts.

In the management of this type drainage should, of course, be insured. The subsoil is generally pervious, so that underdrainage is feasible. The organic-matter content must be maintained by the use of crop residues, manure, and legumes. The phosphorus supply should be increased, preferably by applying fine-ground natural rock phosphate at the rate of about 500 pounds per acre for each year in the rotation until at least three or four tons have been applied, after which 200 pounds per year will maintain the supply. About 4 tons per acre of ground limestone should also be applied, with subsequent applications of about 2 tons every four or five years. For results secured in field trials with these methods of permanent soil improvement, see Tables 4 to 11 in the preceding pages.

Brown Silt Loam on Rock (1226.5)

Brown silt loam on rock occupies 1.98 square miles (1,267 acres), or .28 per cent of the area of the county. In topography it is slightly undulating, like the ordinary brown silt loam. The largest area occurs on the west side of the Kankakee river a short distance northwest of Kankakee, and represents a preglacial ridge or hill.

The surface soil, 0 to 6⅔ inches, is a brown silt loam varying in color from a light to a fairly dark brown. It varies somewhat in physical composition owing to the presence in some places of considerable sand and in other places to the nearness of the rock to the surface, the latter condition resulting in a heavier soil because of the presence of residual clay left from the decomposing limestone. The organic-matter content averages 3.6 percent, or 36 tons per acre—a little lower than the ordinary brown silt loam.

The subsurface usually extends to solid rock, a depth of 18 to 20 inches, tho in some areas the rock is deeper. It varies in physical composition the same as the surface, and usually shows a layer a few inches thick of a heavy reddish clay in the lower part of the stratum, with a thin layer of disintegrated limestone immediately on the rock. It contains an average of 2.8 percent of organic matter.

In the management of brown silt loam on rock the same methods should be followed as are suggested for ordinary brown silt loam. Crops that are well

adapted to withstand somewhat drouthy conditions should be grown, since this type is more likely to suffer from drouth than some other types because of the nearness of the bed rock.

Black Clay Loam (920, 1020, 1120, 1220)

Black clay loam in Kankakee county represents in part the originally swampy and poorly drained upland. It covers a total area of 24.21 square miles (15,494 acres), or 3.61 percent of the area of the county. The topography is flat.

The surface soil, 0 to 6⅔ inches, is a black or dark brown, plastic, granular clay loam containing 5.5 percent of organic matter, or about 55 tons per acre. It varies in physical composition according to the amount of sand and gravel present; local areas are of a sandy or gravelly character. Small areas of peat and muck occur.

The subsurface stratum extends to a depth of 16 to 18 inches. It differs from the surface soil in color, growing lighter with depth, the lower part of the stratum passing into a drab or yellowish silty clay usually containing some gravel. It is quite pervious to water owing to jointing or checking from shrinkage in times of drouth. The organic-matter content is about 2 percent.

The subsoil is usually a drab or dull yellow silty clay frequently containing pebbles of various kinds or concretions of limestone. It is checked and jointed, making it pervious to water and consequently easy to drain.

Black clay loam presents some variations. Here, as elsewhere, boundary lines between different soil types are not always distinct, but the types frequently pass from one to the other very gradually, thus giving an intermediate zone of greater or less width. Gradations between brown silt loam and black clay loam are very likely to occur since they are usually adjoining types. Similar gradations occur between black clay loam and drab clay loam.

Drainage is the first requirement of this type. It is very necessary that the soil be kept in good physical condition, and thoro drainage is essential for this. Every means must be taken to maintain good tilth. While this is one of the best types in the state, yet the clay and humus contained in it give it the property of shrinkage and expansion to such a degree as to be somewhat objectionable at times, especially during drouth. When the soil is wet, these constituents expand, and when the moisture evaporates or is used by crops, they shrink, and the result in times of drouth is the formation of cracks 2 to 4 inches in width and extending to a depth of two feet or more. These cracks permit excessive losses of moisture, with the result that the soil sometimes shrinks so as to "block out" the hills of corn, breaking or tearing the roots and damaging the crop. A good soil mulch will reduce the cracking to some extent.

This type is fairly well supplied with plant food, which is usually liberated with sufficient rapidity by a good rotation and by the addition of moderate amounts of organic matter. The amount of organic matter added must be increased, of course, with continued farming, until the nitrogen supplied is equal to that removed. Altho the addition of phosphorus is not expected to produce marked profit, it is likely to pay its cost in the second or third rotation; and even by maintaining the productive power of the land, the capital invested is protected.

At Urbana, on the South Farm of the University of Illinois, a series of plots devoted chiefly to variety tests and other crop-production experiments ex-

tends across an area of black clay loam. Where rock phosphate has been applied at the rate of 500 pounds an acre a year in connection with crop residues, in a four-year rotation of wheat, corn, oats, and clover (or soybeans), the value of the increase produced per ton of phosphate has been, in three successive rotation periods, $2.13, $4.70, and $6.48, respectively, at the "lower prices" for produce, or $3.04, $6.71, and $9.26, respectively, at the "higher prices." In the live-stock system, the phosphorus naturally supplied in the manure, supplemented by that liberated from this fertile soil, has thus far been nearly sufficient to meet the crop requirements; the increase in crop values per ton of phosphate applied having been, as an average for the twelve years, only $2.26 at the "lower prices," or $3.26 at the "higher prices." These returns are less than half the cost of the phosphorus applied, and in some seasons no benefit appears.

This type is rich in magnesium and calcium, and in the Wisconsin glaciation it sometimes contains plenty of carbonates. With continued cropping and leaching, applications of limestone will ultimately be needed.

Drab Clay Loam (1121, 1221)

Drab clay loam occupies 6.93 square miles (4,435 acres), or 1.03 percent of the area of the county. In topography it is similar to black clay loam.

The surface soil, 0 to 6⅔ inches, is a dark drab, brown, or almost black clay loam.

The subsurface stratum, which is from 6 to 10 inches thick, varies from a dark drab or brownish color to a yellowish drab or olive. A decided change occurs at a depth of 7 to 10 inches, the color becoming much lighter, indicating the presence of less organic matter.

The subsoil is very similar to the subsoil of black clay loam both in color and in perviousness.

In general the type should receive the same treatment as the black clay loam.

Brown Sandy Loam (960, 1060, 1160, 1260)

Brown sandy loam covers an area of 87.89 square miles (56,250 acres), or 13.12 percent of the area of the county. Its formation is due either to the overflow of the lower part of the intermorainal areas during the floods from the melting glaciers, and the deposition of sand, or by the carrying of sand from the shore of the flooded plain onto the upland. It appears principally in the southern part of the county altho there are several large areas north and northeast of Kankakee. The topography is undulating to flat, resembling that of the brown silt loam.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam varying from a light brown to a black. In physical composition it varies from a loam with 50 percent of sand to a very sandy loam with about 75 percent of sand. In many local areas the content of sand may be above or below this, but these areas are too small to be shown on the map. The average sand content of the type is about 60 to 65 percent, and is mostly of medium grade. The organic-matter content varies from less than 5 percent to more than 8 percent, with an average of 6.9 percent, or 69 tons per acre.

The subsurface stratum varies in thickness from 7 to 12 inches, and in color from a dark brown to a brownish yellow. In physical composition it varies even

more than the surface stratum. It contains as an average about 3 percent of organic matter.

The subsoil varies from a yellow sand to a yellow silt, or loess, or even boulder clay. It is chiefly of a silty character, but areas of the sandy phase are so mixed with the silty that a separation of the two is practically impossible.

The type in many places needs drainage, and because of the pervious character of the subsoil this is easily accomplished by tiling. The soil works easily and is in good tilth. For a sandy loam, it is reasonably well supplied with all elements of plant food. Where acidity exists, especially where the subsurface or the subsoil is acid, limestone should be used liberally. Of course, a good rotation including legumes should be practiced and organic manures should be returned to the soil. Where this is done, sufficient phosphorus and potassium are likely to be liberated for satisfactory results for many years, altho ultimately one or both of these elements may need to be applied. This need is likely to be for phosphorus first on the more compact phase and for potassium first on the more sandy areas.

Brown Sandy Loam on Rock (1160.5)

Brown sandy loam on rock constitutes only .27 square mile (173 acres), or .04 percent of the area of the county. The topography is the same as brown sandy loam.

The surface soil, 0 to 6⅔ inches, is a brown sandy loam containing 4.7 percent of organic matter, or 47 tons per acre. It varies somewhat from the typical sandy loam.

The subsurface is a sandy loam containing 2.3 percent of organic matter.

The depth to rock varies only from 16 inches to 30 inches, and in consequence crops are likely to suffer more from drouth on this type than on the common type of brown sandy loam, but the same methods of improvement should be followed.

Gravelly Loam (1090)

Gravelly loam is found in a small area southeast of Aroma, and is of very little importance agriculturally. It occupies a hill of assorted glacial material called a "kame" or a "kame heap," which is known locally as Mount Langman. The surface soil contains 7.66 percent of organic matter. Practically the only use that can be made of this type is pasturing, or possibly the growing of some kinds of fruit, such as grapes. The railroad has been using the gravel.

(b) UPLAND TIMBER SOILS

The upland timber soils are deficient in organic matter owing to the fact that the vegetable material from the trees accumulates upon the surface and is either burned or suffers almost complete decay. The grasses, which furnish large quantities of humus-forming roots, do not grow to any large extent in forests. At the same time, the organic matter that had accumulated before forests began growing on these soils has been largely removed thru processes of decomposition, with the result that the content has become too low for the best agricultural conditions.

Yellow-Gray Silt Loam (1234)

Yellow-gray silt loam occurs in a few irregular areas along the western part of the Kankakee river and along the bluff of the old swamp in the northeastern part of the county. It covers an area of 7.82 square miles (5,005 acres), or 1.16 per cent of the area of the county. In topography it is undulating to rolling, usually having good drainage.

The surface soil, 0 to 6⅔ inches, is a gray or yellowish gray silt loam, incoherent and mealy but not granular. In physical composition it varies with the relation of the type to other types, erosion, which has taken place to a greater or less extent, having removed in places the surface and some subsurface soil, thus exposing the subsoil, or probably the glacial drift. The area in the northeastern part of the county contains considerable sand in small areas—sufficient to class it as sandy loam. The amount of organic matter varies from 2.2 to 3.4 percent, but averages 2.7 percent, or 27 tons per acre. It increases as the type grades into brown silt loam, which usually borders it.

The subsurface stratum varies from 3 to 10 inches in thickness, being thinner on the more rolling areas. In color it is gray, grayish yellow, or yellow. It is somewhat pulverulent but becomes more coherent and plastic with depth. The amount of organic matter averages about 1 percent, or 40 tons per acre.

The subsoil is a yellow or grayish yellow clayey silt or silty clay, somewhat plastic when wet but pervious to water. Till usually composes part of the subsoil.

In the management of yellow-gray silt loam, one of the most essential points is the maintenance or increase of organic matter. This is much more necessary with this type than with brown silt loam because this soil is naturally much more deficient in this constituent, having only about one-half as much. The organic matter prevents the soil from "running together," and gives better tilth under all conditions; on some of the more rolling areas it prevents washing. As it decays, it supplies nitrogen and tends to liberate other plant food, as explained in the Appendix. Other essentials are the application of ground limestone and phosphorus, and the large use of clover, alfalfa, or other legumes, which should be returned to the soil either directly with other crop residues or in manure, thus providing an adequate supply of new nitrogen.

For definite results from the most practical field experiments upon typical yellow-gray silt loam, we must go down into "Egypt," where the people of Saline county, especially those in the vicinity of Raleigh and Galatia, have provided the University with a very suitable tract of this type of soil for a permanent experiment field. There, as an average of duplicate trials each year for the four years 1911 to 1914, the crop values from four acres were $16.44 from untreated land, $18.22 where organic manures were applied in proportion to the amount of crops produced, and $33.58 where 6 tons per acre of limestone and the organic manures were applied—the wheat, corn, oats, and clover (or cowpeas or soybeans) grown in the rotation being valued at the "lower prices" heretofore mentioned. Owing to the low supply of organic matter, phosphorus produced almost no benefit, as an average, during the first two years; but with increasing applications of organic matter the effect of phosphorus is becoming more apparent in subsequent crops. Of course the full benefit of a four-year rotation cannot be realized during the first four years. The farm manure was applied to one field each year, and the fourth field received no manure until the fourth year. Like-

TABLE 14.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

YELLOW-GRAY SILT LOAM, UNDULATING TIMBERLAND; LATE WISCONSIN GLACIATI

Plot	Soil treatment applied[1]	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910
		Bushels or tons per acre								
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.3	59.4	26.2	3.2
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0
	Increase: Bushels or Tons per Acre									
For nitrogen		1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6
For phosphorus		5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8
For potassium		3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6
For nitrogen, phosphorus over phosphorus		6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8
For phosphorus, nitrogen over nitrogen		10.3	21.9	13.1	-2.6	21.5	14.5	-11.2	20.8	4.6
For potassium, nitrogen, phosphorus over nitrogen, phosphorus		4.6	6.4	16.0	2.8	6.6	10.5	2.8	-3.3	-3.0

[1]Crop residues in place of commercial nitrogen after 1911.

[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.

[3]No seed produced: clover plowed under on these plots.

TABLE 15.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$135.12	$193.03
102	Lime	119.74	171.06
103	Lime, nitrogen	124.70	178.15
104	Lime, phosphorus	202.20	288.85
105	Lime, potassium	138.88	198.40
106	Lime, nitrogen, phosphorus	179.41	256.31
107	Lime, nitrogen, potassium	133.54	190.77
108	Lime, phosphorus, potassium	201.35	287.65
109	Lime, nitrogen, phosphorus, potassium	191.22	273.18
110	Nitrogen, phosphorus, potassium	196.62	280.88

Value of Increase per Acre in Thirteen Years

For nitrogen	$ 4.96	$ 7.09
For phosphorus	82.46	117.79
For *nitrogen* and phosphorus over phosphorus	–22.79	–32.54
For *nitrogen* and phosphorus over nitrogen	54.71	78.16
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.81	16.87

[1] Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2] Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

wise, crop residues plowed under during the first rotation may not be fully recovered in subsequent increased yields until the second or third rotation period.

While limestone is the material first needed for the economic improvement of the more acid soils of southern Illinois, with organic manures and phosphorus to follow in order, the less acid soils of the central part of the state are first in need of phosphorus, altho limestone and organic matter must also be provided for permanent and best results.

Table 14 shows in detail thirteen years' results secured from the Antioch soil experiment field located in Lake county on the yellow-gray silt loam of the late Wisconsin glaciation. In acidity this type in Kankakee county is intermediate between the similar soils in Saline and Lake counties.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field, page 9, for further explanations. Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of forty tests (four each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.54 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) pro-

duced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus, and the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

From a comparison of the results from the Urbana, Sibley, and Bloomington fields, we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economical source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement.")

Yellow Silt Loam (1235)

Yellow silt loam is found on the more rolling areas. It comprizes only .92 square mile (589 acres), or .14 percent of the area of the county. It occurs along the north side of the Kankakee river northwest of Kankakee. An area is also found in the northeastern part along the bluff adjoining the old swamp.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow silt loam usually containing sand and some gravel. It naturally varies in physical composition because of its origin. It contains 2.1 percent of organic matter, or 21 tons per acre.

The subsurface is a yellow silt loam which varies largely and may even contain a considerable proportion of gravel and sand. It contains less than 1 percent of organic matter.

The subsoil is a yellow to brownish, well-oxidized material varying from silt or clayey silt to boulder clay. The latter is always present and constitutes a considerable part of the stratum.

One of the best uses to which this type may be put is permanent pasture. As a rule it cannot be satisfactorily cropped in ordinary rotations but it may be used very successfully for long rotations with pasture or meadow much of the time. Both the surface and the subsurface are usually acid, and ground limestone may well be used for legumes in the rotation or even as a top dressing to encourage their growth in pastures. Where this type has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such land the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 16 and 17, and shown photographically in Plates 7 and 8.

In one experiment, a large quantity of typical worn hill soil was collected from two different places. Each lot of soil was thoroly mixed and put in ten

four-gallon jars. Wheat was planted in one series and oats in the other.[1] Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 16.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under usual conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa,

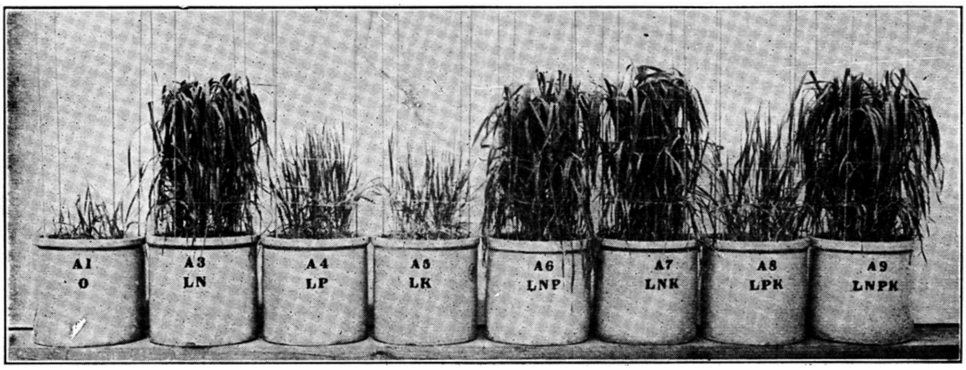

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 16)

TABLE 16.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

[1] Soil for wheat pots, from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains the essential minerals and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same kind of worn hill soil as that used for wheat in the former experiment. The results are reported in Table 17.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced.

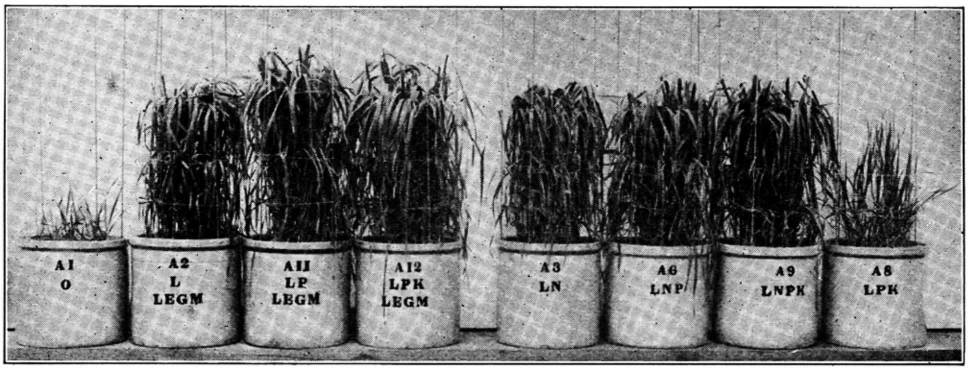

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 17)

TABLE 17.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN MANURE CROPS
(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted. Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 16 in showing the very great need of nitrogen for the improvement of this type of soil,—and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied

with care. As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with erosion, which is sure to occur to some extent, the phosphorus supply will be renewed from the subsoil.

Probably the best legumes for this type of soil are sweet clover and alfalfa. On soil deficient in organic matter sweet clover grows better than almost any other legume, and the fact that it is a very deep-rooting plant makes it of value in increasing the organic matter and preventing washing. Worthless slopes that have been ruined by washing may be made profitable as pasture by growing sweet clover. The blue grass of pastures may well be supplemented by sweet clover and alfalfa, and a larger growth obtained, because the legumes provide the necessary nitrogen for the blue grass.

To get alfalfa well started requires the liberal use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (about 5 tons) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Yellow-Gray Sandy Loam (1064)

Yellow-gray sandy loam occurs in a limited area on the east side of the Iroquois river in the south part of Kankakee county. It comprizes .83 square mile (531 acres), of .12 percent of the area of the county. The topography is undulating to slightly rolling, and the surface drainage is generally good. The type has been produced largely by the carrying of the sand into its present position by the wind.

The surface soil, 0 to 6⅔ inches, is a brownish yellow to grayish yellow sandy loam containing 2.5 percent of organic matter. It is quite variable as to sand content.

The subsurface in some places is a sand or sandy loam while in others it is a silt or silt loam. It contains less than 1 percent of organic matter.

The subsoil varies in the same way as the subsurface, with the exception that till may be found at variable depths.

In the improvement of yellow-gray sandy loam, limestone and legumes are of first importance, and the legume crops should be returned to the soil either directly with other crop residues or in farm manure. For the highest improvement of this soil, either phosphorus or potassium, or both, may be required. As between these two elements, phosphorus should be used on the heavier phase with compact silty subsurface and subsoil, while potassium is likely to be needed more than phosphorus where the substrata are sandy and afford a very deep feeding range for plant roots. Very marked improvement can be made with limestone and organic manures, and whether phosphorus or potassium is to be used is a matter of very secondary importance for future consideration.

TERRACE SOILS

The soils of Kankakee county classed as terrace soils are not true river terraces but are more of the nature of sand and gravel outwash plains produced

by the broad stream that flowed across the county from Indiana at the time of the melting of the glacier. The underlying material varies a great deal. In some places of limited extent, the soil rests directly on solid limestone or on stones varying in size from 2 to 12 inches in diameter, but more often sand or gravel forms the substratum. Many areas contain large numbers of boulders that have remained after the finer material has been carried away. At one time the region shown as terrace was a broad lake, very likely characterized by rather strong currents at first that carried away immense amounts of material and later deposited the fine material that now composes the soil and the sand dunes. Bed rock is not very deep at any place.

Black Clay Loam (1520)

The black clay loam of the terrace constitutes 5.68 square miles (3,635 acres), or .85 percent of the area of the county. The principal areas are north of the Kankakee river east and northeast of Kankakee near the edge of the old swamp. They are of flat topography and were once swamps.

The surface soil, 0 to 6⅔ inches, is a black clay loam usually containing a variable amount of sand and gravel. The organic-matter content is very high—9.3 percent, or 93 tons per acre where collected for analysis—and in some places the soil approaches a muck.

The subsurface soil, represented by a stratum from 8 to 20 inches in thickness, consists of a gravelly clay loam varying from a dark or black to a yellowish drab clay loam. Many of the gravel are limestone. The organic-matter content is higher than that in the subsurface of any other soil in the county, except the peats, being 3.9 percent, or 78 tons per acre.

The subsoil is quite variable, nearly always containing considerable gravel, including some limestone. It is of a drabbish yellow or yellowish drab color. Many cray-fish holes have been made into the subsoil and filled to a very large extent with surface material.

The first need of this type is drainage. All the strata are pervious, so that drainage is very easily effected. The soil is rich in all plant-food elements; with a good rotation and a moderate supply of decaying organic matter to maintain the biochemical activities, large crop yields should be produced. Ultimately the addition of ground limestone may prove beneficial, especially where limestone pebbles and concretions are not abundant in the surface or subsurface.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel is found in various places in Kankakee county, but it is especially well developed along the north side of the Kankakee river northeast of Aroma and in the vicinity of Momence. In topography it is flat to slightly undulating. The substratum of coarse material varies from gravel to coarse sand; it occurs at various depths but probably averages 4 feet. As a rule, the presence of this gravel has provided very good underdrainage, but in some instances it has been necessary to tile-drain. This type covers a total area of 7.95 square miles (5,088 acres), or 1.18 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies in color from brown to black, and in physical composition from a light silt loam to a heavy silt. The organic-matter content is high.

The subsurface is a brown silt loam which changes to yellow at a depth of 16 to 18 inches. It contains much less organic matter than the surface stratum.

The subsoil varies greatly, in some places containing considerable sand and fine gravel. It is generally a yellow clayey silt, pervious, and easily drained. The gravel stratum is a mixture of medium and fine gravel and coarse sand.

This type requires practically the same management as brown silt loam upland prairie. Alfalfa would do well where the soil is well drained and properly treated.

Brown-Gray Silt Loam on Tight Clay (1528)

Brown-gray silt loam on tight clay occurs only to a limited extent on the terrace, covering but 90 acres.

The surface soil is a brown silt loam generally rather high in organic matter, the average being 6.3 percent.

The subsurface soil is a grayish brown silt loam, running into a heavy, nearly impervious clay at a depth of 16 to 20 inches. The thickness of this stratum is about 12 inches, below which is a more pervious subsoil, even gravelly at a depth of 36 to 48 inches.

In topography this type varies from flat to slightly undulating, the undulations consisting in most cases of low hills or ridges of dune sand which are covered with a sandier phase of the type. The flat areas are usually swampy and have required thoro drainage before any crops except hay could be grown. These swamp lands vary greatly in the depth of the brown top soil.

This type of soil is very strongly acid. Ground limestone should be used liberally, and active organic matter should be provided by the growing of legumes and the application of crop residues or manure. Better drainage is one of the essential factors in the improvement of this soil, and where the subsoil is too compact for underdrainage, surface ditches or furrows with adequate outlets must be depended upon to remove most of the excess water. For the highest improvement, phosphorus may also be needed.

Brown Sandy Loam (1560)

Brown sandy loam terrace, next to brown silt loam prairie, is the most extensive type in Kankakee county. It covers an area of 211.83 square miles (135,571 acres), or 31.63 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a brown to black sandy loam. It varies quite widely in two respects; first in its organic-matter content, and second in its sand content. The variations are so irregular as to make practically impossible any separation of the type into subdivisions. It contains areas of shallow peat, peaty loam, black sandy loam, and sand, too small to be shown on the map; and various phases of brown sandy loam occur mixed together in the greatest confusion. A single ten-acre tract may contain, and frequently does contain, several of these phases. The average organic-matter content in the surface soil is about 5 percent.

The subsurface soil varies as widely as the surface stratum. In some of the lighter phases the yellow material begins at a depth of 6 or 7 inches, while in other parts the dark color extends to a depth of 24 inches or more, thus causing the subsurface to vary from a yellow to a black sandy loam. Sometimes strata of clay or silt are found in either of these phases.

The subsoil, too, varies quite widely, with sand as the principal constituent. In the southeastern part of the county very little gravel is present in this stratum, while in the central part and in some of the western areas gravel is frequently met with; and the presence of strata of clay is quite characteristic. Iron concretions are common, and in some places there occur deposits of bog iron ore covering considerable areas. The sand of the subsoil in many places is quite mobile ("quick sand"), so that tiles soon become clogged and dredges partly filled.

Alkali spots are abundant over almost the entire area of brown sandy loam, with the result that some parts are of low agricultural value under present conditions.

Drainage is one of the first requirements for practically all this type. When thoroly drained, most of the type becomes quite productive; but, aside from the alkali spots, most of it is deficient in limestone, especially for such crops as clover and alfalfa. Legume crops should be a part of the rotation, and organic matter should be returned to the soil. As these swamp sand lands are often very deficient in potassium susceptible of liberation, thoro trials should be made on a small scale with about 200 pounds per acre of potassium chlorid ("muriate" of potash) on areas which do not produce satisfactory crops after being well drained. If potassium is needed, it may then be applied either in potassium chlorid or in farm manure. In a few phases, as in those in the region of Wichert, market gardening is profitably practiced, usually with liberal applications of animal manures.

Brown Sandy Loam on Rock (1560.5)

Brown sandy loam on rock occupies 15.16 square miles (9,702 acres), or 2.26 percent of the area of Kankakee county. It is distributed chiefly in two areas, one south of Momence and another in the vicinity of Bonfield. In topography it varies from flat to slightly undulating, requiring artificial drainage in places.

The surface soil, 0 to 6⅔ inches, is a brown to black sandy loam varying quite widely in its sand content. It is mellow and works very easily. In some places clay forms an important constituent and modifies the character of the soil, altho sand is still abundant. These heavy areas are not very extensive; they seem to occur where the limestone is near the surface, and they probably result from its decomposition. The organic-matter content is rather high, varying from about 6 to 9 percent and averaging approximately 8 percent. Some of this type approaches a peaty loam in character.

The subsurface usually extends to rock, which varies in depth from 12 to 20 inches or more. In composition it varies somewhat with the surface, but it oftener contains more of the heavy reddish or brownish clay derived from the decomposition of the underlying limestone. The organic-matter content is about 3 percent, or 60 tons per acre.

Between the subsurface stratum and solid rock occurs a stratum made up principally of limestone fragments, the stones varying in size from 2 inches to a foot or more in diameter, composed almost entirely of magnesian limestone similar to that quarried in the county. Beneath this stratum of differing depth occurs the solid rock. In a few localities the solid rock is found at about 30

inches, and in such places the soil is characterized by lack of drainage in wet weather and the drying out of crops in times of drouth.

Alkali spots exist in many places. Foreign boulders such as granite, syenite, and various crystalline rocks occur in considerable abundance in such places, principally in the lower strata, but all the type constains some of these.

In the management of this type drainage is usually the first essential, but it is very difficult to secure because of the stones. Otherwise methods for improvement are the same as for the more extensive brown sandy loam (1560).

Yellow-Gray Sandy Loam (1564)

Yellow-gray sandy loam occurs in limited areas along the Kankakee river in the eastern half of the county. It covers a total area of 326 acres. It represents that part of the sandy loam that has been affected by the long growth of forests, by which much of the original organic matter has been removed. The topography is flat to undulating.

The surface soil, 0 to 6⅔ inches, is a yellowish gray or grayish yellow sandy loam usually containing from 60 to 75 percent of sand, and in many places, too small to map, would be classed as sand. The organic-matter content is low, averaging only 2.2 percent, or 22 tons per acre.

The subsurface stratum varies from a yellow sandy loam to a yellow sand. It contains .7 percent of organic matter.

The subsoil consists of a yellow sand with an occasional stratum of silty or clayey material.

This type is strongly acid and very deficient in nitrogen and organic matter. An initial application of ground limestone should be made at the rate of at least 4 tons per acre, and subsequently about 2 tons should be applied every four years. Legumes should constitute one-half, or at least one-third, of the crops in the rotation, and should be returned to the soil with crop residues or in manure. Potassium, preferably in the form of kainit, is more likely to prove profitable than phosphorus, except on the heavier phase of the type, but very marked improvement can be made with limestone, legumes, and organic manures. (Note results of experiments reported under *Dune Sand.*)

Dune Sand (1581)

While dune sand is distributed over the entire terrace region, it is especially abundant in the southeastern part of the county in the vicinity of Hopkins' Park. The type covers a total area of 36.69 square miles (23,482 acres), or 5.48 percent of the area of the county. It has originated from the reworking by the wind of sand deposited as bars in the lake or on the old lake shore. In topography it varies widely. The dunes are rarely more than 50 feet in height and more commonly only 20 and 30 feet, but they present a constant change of topography. Many of them are somewhat circular in outline, with a steep slope to the normal leeward, or northeast, and a more gradual slope toward the windward, or southwest. In the extensive dune areas there is no regular arrangement in size, shape, direction, or location.

In some cases the dunes may extend in long ridges for several miles. A good example of this formation occurs in Sections 8, 16, and 22, in Township 31 North,

Range 11 East, where a sand dune extends for a distance of nearly four miles with but one break. There are indications here of an old beach line, as shown by the presence of gravel in the base of the dune. In most cases the dunes are short, irregular hills varying in height, direction, and length. Most of them are covered with black-oaks (*Quercus Marylandica*), which have prevented the recent movement of the sand. In some localities the forests have been removed and disastrous movement has occurred. In surveying the dune region small areas were found in the middle of forests, from which the trees had been removed by some cause, giving the wind a chance to blow the sand. Altho these timber openings were not more than 100 feet in diameter, yet the sand had been scooped out in places to a depth of 20 to 40 feet.

The surface soil, 0 to 6⅔ inches, varies from a yellow sand to a brownish yellow loamy sand composed very largely of material of medium grades. The soil is quite low in organic matter, having only 1 percent, or 10 tons per acre.

The subsurface consists of a yellow sand containing only .3 percent of organic matter. The subsoil is also a yellow sand.

Dune sand contains no limestone, either in the surface, subsurface, or subsoil, and it is exceedingly poor in nitrogen. The total supply of potassium is large, but this is chiefly locked up in sand grains, and consequently not susceptible of liberation by practical means, altho sufficient amounts can usually be made available for very good crops. (On swamp sands and sandy loams long exposed to leaching, potassium is often the first limiting element, especially where a fair supply of humus exists, as in the so-called "black sand.") The phosphorus content of sand soils is not high, but it exists to a considerable extent in other constituents than sand grains. The United States Bureau of Soils separated glacial sand and sandy loam into coarse, medium, and fine particles, analyzed each for phosphorus, and found that as an average of the two soils the fine portion was eighteen times as rich as the coarse. Corn on sand land "fires" very badly; that is, the lower leaves dry up. This is partly due to the fact that the soil is low in the element nitrogen and there is a translocation of the nitrogen from the lower leaves to the upper to continue growth. This drying up is usually attributed to lack of moisture, but lack of moisture is not the primary cause. The fact should be remembered that less moisture is required to produce a crop on a soil plentifully supplied with plant food than to produce one on a poor soil.

In the management of this type, the two things of first and by far the greatest importance are the addition of limestone and of organic matter. While sand soil is not high in acidity, it is entirely devoid of limestone to a depth of more than 40 inches, and for satisfactory results an initial application of 4 to 6 tons per acre should be made, and this supply maintained by subsequent applications of 2 or 3 tons every four or five years. Organic matter is needed to increase the moisture content, to furnish nitrogen, and to prevent blowing. Sand possesses very little cohesion, so that it is moved quite readily by the wind. In fact, wind erosion on this soil is worse than water erosion on other soils, and unless some special means is used, especially on the more sandy areas, to prevent the movement by wind action, ultimate ruin of the soil will result. When organic matter is added, it acts as a feeble cement, but yet sufficiently strong to bind the soil particles together and prevent blowing. The moisture-holding capacity of clean

TABLE 18.—CROP YIELDS IN SOIL EXPERIMENTS, GREEN VALLEY FIELD

Sand ridge soil		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Value of 6 crops	
Plot	Soil treatment applied	Bushels per acre						Lower prices	Higher prices
401	None	68.7	56.3	49.7	18.3	32.9	35.3	$94.35	$134.78
402	Lime	68.2	42.0	35.9	19.0	17.8	29.5	78.48	112.11
403	Lime, nitrogen	68.6	65.4	44.4	23.5	62.9	58.9	127.74	182.48
404	Lime, phosphorus	30.3	24.9	20.3	16.7	10.4	13.1	44.92	64.17
405	Lime, potassium	23.1	20.1	16.9	16.5	8.4	12.8	38.82	55.46
406	Lime, nitrogen, phosphorus	57.4	69.8	51.9	26.8	70.8	64.7	125.34	178.91
407	Lime, nitrogen, potassium	70.0	72.9	54.7	36.5	74.8	73.6	142.82	204.03
408	Lime, phosphorus, potassium	49.8	39.6	36.9	13.7	18.3	27.7	67.31	96.16
409	Lime, nitrogen, phosphorus, potassium	69.5	69.8	47.8	36.2	66.4	73.6	136.47	194.97
410	Nitrogen, phosphorus, potassium	57.2	66.1	50.0	26.5	66.0	71.9	123.97	177.10
Average gain for nitrogen		23.5	37.8	22.3	14.3	55.0	46.9	73.37	104.82
Average gain for potassium over nitrogen		6.8	3.8	3.1	11.2	3.8	11.8	17.88	25.54
Average gain for phosphorus over nitrogen		–5.9	.7	.3	1.5	–.3	2.9	.22	.32

medium sand, in a test at this station, was increased 40 percent by the addition of 5 percent of peat, and 85.7 percent by 10 percent of peat.

Rye is one of the hardy non-legumes often grown on sand soil, but this does not sufficiently cover the soil to protect it from blowing. Furthermore it is a common practice to sell the straw as well as the grain, and this leaves very little organic matter to be turned back into the soil. A practice that could be followed to good advantage in favorable seasons would be to sow cowpeas after rye, following the binder with the drill, and then later drill rye in the cowpeas without cutting them or turning them under. This would serve to protect the soil from blowing, as well as furnish a supply of nitrogen and organic matter to the soil, and would undoubtedly result in the improvement of this type. When potash salts can be secured at reasonable cost, their use is likely to produce profitable results, at least temporarily, in getting under way systems of permanent improvement on this soil. This applies more especially to the level areas which were originally sandy swamps.

For six years experiments were conducted on sand ridge soil on the experiment field near Green Valley, Tazewell county. The soil varies from a very sandy loam to a slightly loamy sand that is easily drifted by the wind when not protected by vegetation. This field was broken out of pasture in 1902. In Table 18 are reported all results secured in the six years from that part of the Green Valley field where nitrogen as well as other elements were supplied in commercial form.

Plot 1, especially, and also Plot 2 in this series, were naturally more productive than the other plots, and were therefore selected as the check plots, in accordance with the regular custom of the Experiment Station to use the most productive land for the untreated check plots if any differences are apparent when the field is established, as was the case in this instance. Plot 1 serves only as a check against the lime treatment; the average of Plots 2, 4, 5, and 8 gives a more reliable basis of comparison for ascertaining the effect of nitrogen. A four-year rotation of corn, corn, oats, and wheat was practiced.

To facilitate summarizing the results of the six years, the total value of the six crops from each plot is shown in the last column, and at the bottom of the table are shown the average increases in yield for each year and the total value of the six years' increase: (1) for nitrogen under the four conditions; (2) for phosphorus in addition to nitrogen (two tests each year); and (3) for potassium in addition to nitrogen (two tests each year). Nitrogen is so clearly the limiting element that the only question regarding phosphorus and potassium is, Will either of them effect a further increase after nitrogen has been applied?

As an average of four tests covering six years, the addition of nitrogen to this sand soil produced increases valued, at the lower prices, at $73.37 an acre, or an average of $12.23 a year. The nitrogen cost $15 a year for 100 pounds of the element in dried blood. In one instance the increase produced actually exceeded in value the cost of the nitrogen applied, if the cost and effect of the potassium be disregarded. Thus, the total value of the six crops from Plot 5, treated with lime and potassium, was $38.82, while $142.82 was the corresponding value of Plot 7, which differed from Plot 5 only by the addition of nitrogen. Under these conditions 600 pounds of nitrogen costing only $90 produced an increase of $104 per acre in six years.

So far as we have discovered, this is the only instance where the use of commercial nitrogen has paid its cost in the production of ordinary farm crops in Illinois, and even here we must not overlook the fact that $15 worth of potassium was associated with $90 worth of nitrogen where this enormous increase was produced. While potassium without nitrogen produces no benefit on this sand soil, when applied with nitrogen potassium costing $15 produced an average increase valued at $13.10 per acre in six years, but in this case the influence and cost of the associated nitrogen must not be ignored. In no case did the total increase pay for the combined cost of the elements involved when nitrogen was one of them. Potassium is evidently the second limiting element in this soil where decaying organic matter is not provided, but the limit of potassium is very far above the nitrogen limit.

During the six years Plot 7, receiving nitrogen and potassium, produced a total of 291.3 bushels of corn (an average of 72.5 bushels a year), 54.7 bushels of oats, and 36.5 bushels of wheat, per acre. To produce the increase of Plot 7 over Plot 5 would require about 75 percent of the total nitrogen applied. Thus, there was a loss of 25 percent of the nitrogen applied, which is a smaller loss than usually occurs where commercial nitrogen is used. Without doubt larger yields would have been produced, especially of corn, if 150 or 200 pounds of nitrogen per acre per annum had been used, which would have increased the cost of nitrogen to $22.50 or $30 per acre each year.

It need scarcely be mentioned that commercial nitrogen is used in these and other experiments in Illinois only to help discover what elements are limiting the crop yields. It should never be purchased for use in general farming, but, if needed, should be secured from the atmosphere by growing legume crops and returning them to the soil directly or in manure. It is interesting to note that on the sand soil the six years' increase from $15 worth of phosphorus (even when applied with nitrogen) is valued at only 22 cents.

On three other series of plots on the Green Valley soil experiment field a three-year rotation of corn, oats, and cowpeas was practiced, every crop being

represented every year. On plots receiving lime and phosphorus, and legume crops as green manure, the yield of corn was 45.6 bushels in 1906 and 67.8 bushels in 1907, as compared with a yield of 70.8 bushels and 64.7 bushels on Plot 6 of Series 400 receiving lime, phosphorus, and nitrogen (see Table 18), and with 10.4 bushels and 13.1 bushels on Plot 4 of the same series, to which no nitrogen was applied. On other plots receiving comparable treatment, where lime, phosphorus, and potassium were used with nitrogen-gathering legume crops as green manure, the corn yields in the three-year rotation were 54.6 bushels in 1906 and 51.5 bushels in 1907, as compared with 66.4 bushels and 73.6 bushels on Plot 9 of Series 400, to which nitrogen was applied, and with 18.3 bushels and 27.7 bushels on Plot 8, which received no nitrogen.

The use of limestone, crop residues, and farm manure, and the growing of legume crops are the only recommendations made for the improvement of these well-drained sand soils, altho, until more organic matter is supplied, further tests may show profit from potassium. Cowpeas and soybeans are well adapted to such soil, and they produce very large yields of excellent hay or grain very valuable for feed and also for seed. Under the best conditions and with good preparation, sweet clover can be grown in good seasons with proper soil treatment. With an abundance of limestone and moderate manuring, alfalfa can also be grown, more than five tons of alfalfa hay per acre in one year having been produced on part of the Green Valley field. Soybeans, sweet clover, and alfalfa should be inoculated with the proper nitrogen-fixing bacteria. Other possibilities of this type may be shown by the use to which it is put in the vicinity of Wichert, where truck farming is carried on quite extensively. Where heavily manured, this dune sand has become very valuable for growing asparagus and several other crops.

(d) LATE SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat is found in comparatively small areas on both upland and terrace. It covers a total area of 2.73 square miles (1,748 acres), or .41 percent of the area of the county. The soil to a depth of at least 30 inches consists of organic matter derived from mosses, sedges, and grasses.

The surface soil, 0 to 6⅔ inches, is a black or brownish peat more or less decomposed. The drained areas have undergone greater decomposition because of better aeration, while the undrained areas have changed but little. The content of organic matter varies from 39 to 58 percent, with an average of 46.5 percent, or 230 tons in the one million pounds of the surface soil of an acre.

The subsurface soil, 6⅔ to 20 inches, consists of black or brown peat that usually shows the texture of the material from which it was produced. The organic-matter content is about 31 percent.

The subsoil, 20 to 40 inches, is ordinarily a brown peat, altho in small areas sand or silt, almost invariably of a drab color, may form the subsoil below 30 inches.

Because of lack of drainage, this type of soil in Kankakee county has not been cultivated to a large extent. It is used mostly for pasture, and probably this is the best use to which it can be put. Tile drainage is not usually satisfactory because the soft peat soon permits the tile to get out of line and this

seriously interferes with drainage. These soils frequently contain alkali that irritates the skin. The term "itch dirt" is often applied to them. Where thoro drainage can be provided either by open ditches or by laying tiles deep enough to secure a solid bed for them, very marked improvement can be made in the productive power of deep peat by the liberal use of potassium, which is by far the most deficient element.

In Table 19 are given all results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which however, were cropped the same as the plots.

The results of the four years' tests, as given in Table 19, are in complete harmony with the information furnished by the chemical composition of peat soil. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one-third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

The use of 700 pounds of sodium chlorid (common salt) produced no appreciable increase over the best untreated plots, indicating that where potassium is itself actually deficient, salts of other elements cannot take its place.

Applications of 2 tons per acre of ground limestone produced no increase in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

TABLE 19.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL (Bushels per acre)

Plot No.	Soil treatment for 1902	Corn 1902	Corn 1903	Soil treatment for 1904	Corn 1904	Corn 1905	Four crops
1	None..................	10.9	8.1	None..................	17.0	12.0	48.0
2	None..................	10.4	10.4	Limestone, 4000 lbs.....	12.0	10.1	42.9
3	Kainit, 600 lbs.........	30.4	32.4	Limestone, 4000 lbs.... Kainit, 1200 lbs......	49.6	47.3	159.7
4	Kainit, 600 lbs....... Acidulat'd bone, 35 lbs.	30.3	33.3	Kainit, 1200 lbs...... Steamed bone, 395 lbs.	53.5	47.6	164.7
5	Potassium chlorid, 200 lbs.............	31.2	33.9	Potassium chlorid, 400 lbs.............	48.5	52.7	166.3
6	Sodium chlorid, 700 lbs...	11.1	13.1	None..................	24.0	22.1	70.3
7	Sodium chlorid, 700 lbs...	13.3	14.5	Kainit, 1200 lbs........	44.5	47.3	
8	Kainit, 600 lbs.........	36.8	37.7	Kainit, 600 lbs.........	44.0	46.0	164.5
9	Kainit, 300 lbs.........	26.4	25.1	Kainit, 300 lbs.........	41.5	32.9	125.9
10	None..................	14.9[1]	14.9	None..................	26.0	13.6	69.4

[1]Estimated from 1903; no yield was taken in 1902 because of a misunderstanding.

Reducing the application of kainit from 600 to 300 pounds for each two-year period, reduced the yield of corn from 164.5 to 125.9 bushels. The two applications of 300 pounds of kainit (Plot 9) furnished 60 pounds of potassium for the four years, an amount sufficient for 84 bushels of corn (grain and stalks). Attention is called to the fact that this is practically the difference between the yield of Plot 9 (125.9 bushels) and the yield obtained from Plot 2 (42.9 bushels), the poorest untreated plot.

[1]In 1904 the yields were taken from quarter-acre plots because of severe insect injury on the other parts of the field.

Medium Peat on Clay (1402)

Medium peat on clay occurs in swampy areas similar in location to those of deep peat, but it has not developed to a greater thickness than 30 inches. It covers a total area of 1.06 square miles (678 acres), or .16 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a brown to black peat, the amount of decomposition, which determines the color, varying with cultivation and drainage. It contains 37.4 percent of organic matter.

The subsurface, which is the stratum between the plowed soil and the clay, is usually a brownish peat similar to the corresponding stratum in the deep peat. In the classification adopted by this station, medium peat varies from 12 to 30 inches in total depth to the earthy subsoil. Consequently, the subsurface varies greatly in thickness, but it is sampled to a depth of 20 inches. It contains about 23 percent of organic matter.

The subsoil consists of a silty clay and almost invariably is of a light drab or bluish color owing to the deoxidation of the iron.

Drainage may be provided without unusual difficulty because tiles may usually be placed in the clay, which affords a good bed for them.

The treatment for this type is the same as for deep peat (1401), but thoro trials should be made with potassium in advance of extensive use, for the surface and subsurface strata sometimes contain sufficient potassium in connection with mineral particles deposited from repeated overflows. (Note results of experiments hereinafter reported under *Peaty Loam on Rock.*)

Medium Peat on Sand (1402.2)

Medium peat on sand occurs in a few small areas in the terrace region. It covers a total of 1.71 square miles (1094 acres), or .26 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies from a brownish to a black peat somewhat decomposed and mixed with more or less sand. The lack of uniformity as to sand content gives a wide variation in composition. As an average, about 38 percent of organic matter is present.

The subsurface extends to a depth of 12 to 20 inches, passing into a drab sand, which continues to an indefinite depth. This stratum contains about 18 percent of organic matter.

As in the case of the other peats, drainage is necessary before cultivation can take place. For the improvement of this type the same treatment is recommended as for deep peat.

Peaty Loam on Sand (1410.2)

Peaty loam on sand occurs in areas somewhat similar to the preceding peaty types. It comprizes 6.15 square miles (3,936 acres), or .92 percent of the area of the county. The topography is flat.

The surface soil, 0 to 6⅔ inches, is a black peaty loam consisting of a mixture of white sand and organic matter. The relative amounts of these constituents vary quite widely, and within the type are found many areas, too small to be mapped separately, of peat and of sandy loam high in organic matter. The organic-matter

content of the surface soil averages lower than is ordinary for peaty loams, being as low as 10 percent in places.

The subsurface soil is as variable as the surface. It usually passes into sand at a depth of 12 to 24 inches. In general, the deeper the black soil extends the better adapted the type is to the growing of crops. This is especially true in the growing of truck crops, where the deeper soil is of decided advantage. This stratum ordinarily contains about 3 percent of organic matter but it varies greatly in this respect.

The subsoil varies somewhat, but it usually consists of a yellow or drabbish yellow sand. Borings may frequently be procured that show strata of clay or silt a few inches in thickness.

Good drainage is the first requirement of this type. In general the methods for improvement are the same as for peaty loam on rock described below. Most areas require the application of potassium in order to produce well. This is true especially of those areas where the soil contains little or no clay. Considerable feldspathic sand is present, but its potassium content is chiefly locked up in the sand grains and not susceptible of liberation by practical means. Alkali is frequently present in sufficient quantities to do considerable injury, more particularly to the corn. The alkali is frequently of such a character that it irritates the skin, causing an itching sensation, and such soil is locally known as "itch dirt." On such soil manure usually gives temporary benefit, while thoro underdrainage will gradually remove the injurious alkali.

Peaty Loam on Rock (1410.3)

Peaty loam on rock occurs in limited areas, occupying only 1.39 square miles (890 acres), or .21 percent of the area of the county. It is found in areas similar in topography and drainage to those of the other peats and peaty loams.

The surface soil, 0 to 6⅔ inches, contains about 12 percent or more of organic matter mixed with a large proportion of white sand. It varies in the same way as the peaty loam on sand. The subsurface as a rule contains more organic matter than that of the peaty loam on sand and is usually underlain by rock at depths varying from 16 to 30 inches.

Drainage is the first requirement of this type, but because of the underlying rock it is very difficult or almost impossible of accomplishment in some areas.

The Momence soil experiment field is located in Section 6, Township 30 North, Range 11 West of 2d P. M., about three miles south of Momence, on peaty swamp soil (peaty loam on rock, 1410.3) which is underlain with impure limestone at a depth of two to three feet, with about 12 inches of yellow sandy subsoil between the black peaty soil and the underlying rock.

A part of Plots 101 and 102 and a smaller part of the other plots extend over somewhat different land, where the soil contains sufficient available potassium to produce a medium crop of corn in a good season, but most of the area under experiment is fairly representative of the most non-productive phase of this peaty swamp soil. There are large areas of swamp soil in Kankakee and adjoining counties of very low productive capacity which will respond to the same treatment as this field.

Series 100 consists of ten tenth-acre plots numbered from 101 to 110. The treatment applied to these different plots is called a "complete fertility test."

TABLE 20.—CROP YIELDS IN SOIL EXPERIMENTS, MOMENCE FIELD, 1902 TO 1915

Plot	Soil treatment applied	Corn 1902	Corn 1903	Corn 1904	Corn 1905	Corn 1906	Corn 1907	Oats 1908	Corn 1909	Corn 1910	Corn 1911	Corn 1912
		Bushels per acre										
101	None	6.9	14.9	4.8	6.8	6.8	.3	16.3	8.4	.3	9.2	5.8
102	Lime	5.5	7.1	20.1[1]	33.9[1]	52.6[1]	14.9[1]	23.1	16.0	.9	15.2	7.4
103	Lime, nitrogen	0.0	3.6	1.3	4.1	5.3	.4	15.6	3.8	1.1	8.2	3.8
104	Lime, phosphorus	1.3	4.6	.4	1.8	1.9	.2	14.1	1.2	.1	7.0	1.6
105	Lime, potassium	23.7	72.2	34.6	41.4	50.0	16.2	21.6	39.2	20.2	62.0	36.2
106	Lime, nitrogen, phosphorus	0.	3.9	.6	1.6	4.5	.4	15.6	1.8	1.7	11.2	7.2
107	Lime, nitrogen, potassium	19.7	71.1	33.5	38.5	53.1	16.5	19.4	49.2	23.8	62.2	44.2
108	Lime, phosphorus, potassium	32.0	73.1	42.0	36.3	59.4	19.9	20.3	55.8	37.4	70.4	51.4
109	Lime, nitrogen, phosphorus, potassium	25.2	66.8	39.2	42.9	65.6	25.1	26.6	66.2	40.4	81.8	69.0
110	Nitrogen, phosphorus, potassium	24.1	70.4	19.0[2]	24.8[2]	51.3	23.4	26.6	61.2	29.0	65.2	59.6

[1] Potassium sulfate was applied to Plot 102 in 1904, 1905, 1906, and 1907.
[2] No potassium was applied to Plot 110 in 1904 and 1905.
[3] Corn at 35 cents a bushel, oats at 28 cents.
[4] Corn at 50 cents a bushel, oats at 40 cents.

It includes trials with applications of the elements nitrogen, phosphorus, and potassium, singly, in all possible double combinations, and all three together. The plan will be easily understood by reference to the tables.

Nitrogen is applied in about 800 pounds of dried blood per acre each year. This furnishes about 100 pounds of nitrogen, or as much as is contained in 100 bushels of corn. Of course the nitrogen is purchased and applied in readily available commercial form in order to ascertain as quickly as possible whether the soil is in need of that element. Where this is found to be the case it simply indicates that in farm practice more nitrogen should be obtained from the air by means of leguminous crops, as is being done in our rotation experiments, and not that commercial nitrogen should be bought and applied to the soil.

Phosphorus is applied in about 200 pounds of steamed bone meal per acre each year. This furnishes 25 pounds of phosphorus, or more than is contained in a 100-bushel crop of corn, the grain containing about 17 pounds and the stalks 6 pounds of that element.

Potassium is applied in the form of potassium chlorid or potassium sulfate (each containing about 42 percent of potassium). About 200 pounds of the salt is applied the first year, and 150 pounds per acre each year afterward. One hundred bushels of corn contain about 19 pounds of potassium in the grain and 2 pounds in the cobs, and the corresponding three tons of stalks contain about 52 pounds of that element. If the stalks are left on the land or all returned in manure, well distributed, the annual loss in potassium is only about 20 pounds for a very large crop of corn. Table 20 shows the results which were obtained during a period of fourteen years, 1902 to 1915. (It should be stated that altho a small amount of lime was applied to certain plots in this field in the beginning of the experiment, the subsequent analysis of soil samples taken at the time the field was located shows that the soil is not in need of lime.)

During the fourteen years the field has been under the control of the University, thirteen corn crops and one oat crop have been grown. The average yield of corn on the four[1] plots receiving no potassium has amounted to but 3.6 bushels per acre, while the average yield of the four[1] plots treated with potassium, at the average rate of about 150 pounds of potassium sulfate per acre per annum, has amounted to 43.6 bushels.

At the lower prices (35 cents for corn and 28 cents for oats), potassium has increased the crop values by $163.10 on Plots 105 and 107, averaged, as compared with the average return from Plots 103 and 104. This gives an average annual return of $11.65 per acre for potassium costing $3.78 at 6 cents a pound, which corresponds to $50.40 a ton for potassium sulfate or potassium chlorid (often incorrectly called "muriate of potash"). Under normal conditions potassium chlorid is the most economical form to use, and when purchased in carload lots by the cooperation of a group of farmers, the cost is usually less than $45 a ton.

After potassium was applied, phosphorus then became of some value, increasing the returns from $175.41 on Plot 105 to $207.74 on Plot 108. The increase of $32.33 is not quite enough to pay for the phosphorus, which cost $35 at $25 a ton for steamed bone, but the comparison between Plot 107 (LNK) and Plot 109 (LNPK), showing an increase of $55.50, indicates that phosphorus

[1] Plots 102 and 110 are not included in the averages.

may be profitable for use where both potassium and nitrogen are provided. This would require, however, that the nitrogen be secured by legumes grown in the crop rotation or applied in farm manure, as the increase from commercial nitrogen on Plot 109, even when the nitrogen was applied in addition to both potassium and phosphorus (compare with Plot 108), was only $30.36 for the fourteen years, while the cost of the dried blood was about $190.

Plates 9 and 10 show the crops growing on the Momence field in 1903 on Plots 101, 2, 3, 4, and 5, in the order given.

The upper view in Plate 9 shows Plot 1, to which no treatment was applied. On the right, looking over Plots 2, 3, and 4, we see Plot 5, to which potassium was applied. The lower view in Plate 9 shows Plot 2, to which lime only was applied. On the right we see the good corn in Plot 5, beyond Plots 3 and 4.

The upper view in Plate 10 shows Plot 3, to which nitrogen was applied, on the right of which is Plot 4, with Plot 5 beyond. The lower view in Plate 10 shows Plot 4 (phosphorus) on the left (4.6 bushels per acre), and Plot 5 (potassium) on the right, where the corn yielded 72.2 bushels to the acre.

In Tables 21 and 22 are recorded the results from Series 200 and Series 300 of the Momence experiment field, for the years 1904 to 1914.

The work was not begun on these series until 1904. A rotation consisting of two crops of corn, one of oats, and one of clover has been practiced. Instead of applying nitrogen in commercial form as on Series 100, the nitrogen has been provided in legume crops, cover crops, and crop residues in the system of grain farming, and in farm manures in the live-stock system. The legume cover crops and crop residues have been made use of since the beginning, but no manure was applied till 1908, after the first clover crop of 1907. The manure was applied in proportion to the crop yields. Where larger crops were produced, proportionately more manure was subsequently applied; and, consequently, more manure was applied to Series 300 than to Series 200. The phosphorus was applied in the form of steamed bone meal carrying 12½ percent phosphorus, at the rate of 200 pounds per acre per annum. No potassium has been applied to Series 200, but potassium has been applied to the whole of Series 300 at the rate of 150 pounds of potassium sulfate per acre per annum. Common salt (sodium chlorid) was applied to the north half of all the plots of Series 200 at the rate of 600 pounds per acre in the spring of 1908. So far as it is possible to observe, no effect has been produced by the salt.

The land on which Series 200 and Series 300 are located is naturally more productive than that on which Series 100 is located. The untreated land of Series 200 will produce under favorable conditions 10 to 15 bushels of corn per acre. The south half of Plot 202 occupies the area of an old stack bottom. For this reason the yields from that plot are larger than normal, at least for the first three or four years. The yields from Plots 201 and 203 were also thus influenced but not to the same extent.

As an average of the returns from Plots 301, 305, and 310 (compare with 201, 205, and 210) potassium increased the crop values by $46.76 per acre during the four years 1904 to 1907, or by $11.69 a year, at a cost of $3.78, but during the next eight years the average yearly increase for potassium alone was only $4.07, which is not much above its cost. When used in addition to manure, the potassium did not pay its cost.

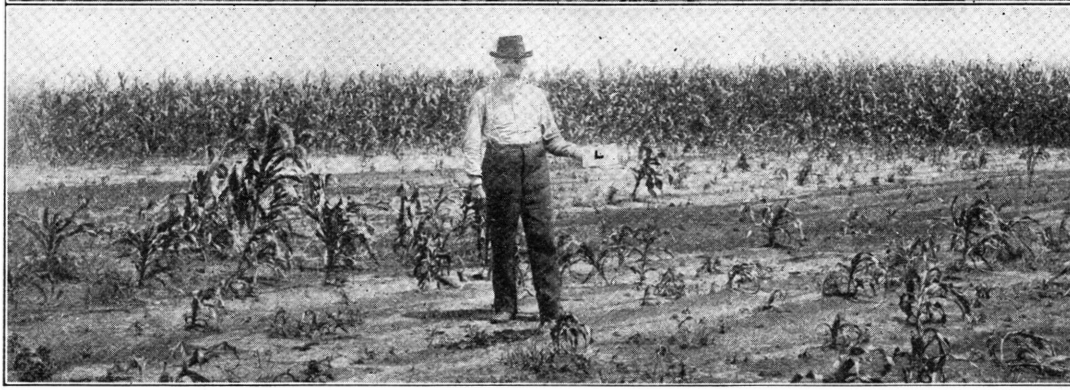

Plate 9.—Corn on Peaty Swamp Land, Momence Field, 1903. Upper View: No Treatment. Low

PLATE 10.—CORN ON PEATY SWAMP LAND, MOMENCE FIELD, 1903. UPPER VIEW: NITROGEN. LOW
ON LEFT, POTASSIUM ON RIGHT

TABLE 21.—CROP YIELDS IN SOIL EXPERIMENTS, MOMENCE FIELD, 1904 TO 1

Plot	Soil treatment applied	Corn 1904	Corn 1905	Oats 1906	Clover 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Corn 1912	Co 19
		Bushels or tons (clover) per acre									
201	None	14.2	11.4	29.4	0	9.2	19.0	36.9	.21	18.6	12
202	Residues	20.1	16.1	32.2	0	8.2	25.2	37.5	Turned	32.2	24
203	Manure	13.4	10.1	24.4	0	11.8	27.8	38.8	.23	35.8	24
204	Manure, cover crop	6.3	6.6	25.3	0	14.2	25.8	46.9	.44	36.6	17
205	None	4.4	5.6	21.2	0	8.2	17.0	48.1	.29	16.2	9
206	Phosphorus	8.7	8.6	23.4	0	14.0	16.0	51.3	.45	18.2	15
207	Residues, phosphorus	10.9	10.1	30.6	0	6.0	17.6	42.8	Turned	27.4	18
208	Manure, phosphorus	1.5	8.9	30.9	0	17.4	17.6	52.2	.80	41.8	12
209	Manure, cover crop, phosphorus	9.4	10.8	38.1	0	25.2	24.4	62.5	.58	51.6	23
210	None	6.5	10.0	29.4	0	8.6	14.4	45.0	.29	17.8	11

[1] Corn at 35 cents a bushel, oats at 28 cents, soybeans at 70 cents, clover at $7 a ton.
[2] Corn at 50 cents a bushel, oats at 40 cents, soybeans at $1, clover at $10 a ton.

TABLE 22.—CROP YIELDS IN SOIL EXPERIMENTS, MOMENCE FIELD, 1904 TO 1

Plot	Soil treatment applied	Corn 1904	Corn 1905	Oats 1906	Clover 1907	Corn 1908	Corn 1909	Oats 1910	Clover 1911	Corn 1912	Co 19
		Bushels or tons (clover) per acre									
301	Potassium	34.9	41.5	36.6	.10	20.2	44.4	35.6	.26	39.4	41
302	Potassium, residues	35.5	35.6	38.1	.28	12.4	54.0	38.8	Turned	38.8	43
303	Potassium, manure	41.1	44.1	40.3	.30	20.0	58.4	39.1	.67	49.8	47
304	Potassium, manure, cover crop	38.5	40.5	33.1	.10	22.6	47.2	40.0	.59	49.8	43
305	Potassium	42.9	45.2	41.2	.48	25.6	48.2	43.8	.71	44.2	45
306	Potassium, phosphorus	45.9	47.7	41.6	1.03	22.0	47.4	41.3	.98	52.0	42
307	Potassium, phosphorus, residues	44.4	50.5	45.3	.40	15.8	53.6	40.0	Turned	45.2	41
308	Potassium, phosphorus, manure	54.4	54.9	44.7	.33	29.6	59.4	53.1	1.13	65.2	49
309	Potassium, phosphorus, cover crop, manure	52.2	55.5	45.9	.05	23.8	54.2	51.6	.98	57.8	45
310	Potassium	30.3	37.5	35.3	.08	16.2	45.0	35.9	.20	33.6	36

[1] Corn at 35 cents a bushel, oats at 28 cents, soybeans at 70 cents, clover at $7 a ton.
[2] Corn at 50 cents a bushel, oats at 40 cents, soybeans at $1, clover at $10 a ton.

Plots 3 and 4 of Series 200 received an average of 3.7 tons of manure per acre in the spring of 1908 and 5.6 tons in 1912. The return in the eight crops was $13.24 for the 9.3 tons, or $1.42 per ton. On Series 300 the corresponding return was $5.02 for 16 tons of manure, or 31 cents per ton, when used in addition to potassium, the manurial value of the cover crop on Plot 4 being included in both cases.

Phosphorus did not produce sufficient increase, at the lower prices for produce, to pay its cost.

The plain conclusion to be drawn from these investigations is that either potassium or manure should be used to begin the improvement of this type; and when good crop yields are secured, more and more manure should be returned, and the application of commercial potassium may then be greatly reduced, or possibly ultimately discontinued. Of course, if some other soil on the farm needs the manure even more because of deficiency in both potassium and nitrogen, one may use less manure and more potassium on the peaty swamp land.

Mixed Loam (1454)

Mixed loam occurs in small areas along the streams and represents the flood plains. It covers a total of only 3.84 square miles (2.457 acres). In general, the drainage systems of Kankakee county are of so recent formation that comparatively small flood plains have been developed. In many places the flood plain is black clay loam, or even peat, while in others it is a sandy loam, but all are so badly mixed that it is impossible to separate them.

The surface soil, 0 to 6⅔ inches, consists of a brown mixture of soil constituents quite variable in different places, so much so that it is impossible to show the different areas on the map. This surface soil contains about 9.7 percent of organic matter, but this varies quite largely.

The subsurface soil does not differ materially from the surface, except that it grades into lighter colored material of smaller organic-matter content.

The subsoil frequently is of a brownish or brownish-yellow color and consists of a mixture of varied proportions of sand, silt, and clay.

This type needs drainage and good cultivation. It is doubtful whether any applications would prove profitable unless it might be manure or legume crops turned under on the more sandy areas.

Clayey Muck (1413)

Clayey muck is limited to a single area of 90 acres located mostly in Section 29, Township 32 North, Range 13 East, occupying a depression that was once a lake or a swamp. A luxuriant growth of grasses and sedges has taken place which has furnished the organic matter. In topography the type is flat, but it occupies more of a distinct depression than black clay loam usually does.

The surface soil, 0 to 6⅔ inches, is a black, plastic, granular, humous, clayey material containing 22.6 percent of organic matter. The subsurface contains the same amount of organic matter, while the subsoil contains but half as much and becomes lighter in color altho still quite heavy.

The first requirement of this type is drainage. It is rich in all plant-food elements, and is neutral or very slightly acid but exceedingly rich in calcium, which is probably held in organic compounds. It is doubtful whether the addition of limestone would be profitable.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletins

76 Alfalfa on Illinois Soils
94 Nitrogen Bacteria and Legumes
115 Soil Improvement for the Worn Hill Lands of Illinois
125 Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois
181 Soil Moisture and Tillage for Corn
182 Potassium from the Soil
190 Soil Bacteria and Phosphates

Circulars

82 Physical Improvement of Soils
110 Ground Limestone for Acid Soils
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?
129 The Use of Commercial Fertilizers
149 Results of Scientific Soil Treatment: Methods and Results of Ten Years' Soil Investigation in Illinois
165 Shall We Use "Complete" Commercial Fertilizers in the Corn Belt?
167 The Illinois System of Permanent Fertility
181 How Not to Treat Illinois Soils
186 The Illinois System of Permanent Fertility from the Standpoint of the Practical Farmer: Phosphates and Honesty

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it truthworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while

his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries will match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil-type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are: (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, such as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprizing undecomposed and partially decayed vegetable or organic material	
	Mineral matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sand	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

[1]25 millimeters equal 1 inch.

Further discussion of these constituents is given in Circular 82.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—Soils with 15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—Soils with 15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and a little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin,

and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to furnish or liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitrous acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish, or liberate, organic and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure. Bacterial action is also promoted by the presence of limestone.

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farmyard dung."

nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt-over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are *not* made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, alfalfa, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

To be sure, these are large yields, but shall we try to make possible the production of yields only a half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the ten

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce		Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Kind	Amount					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain........	50 bu.	71	12	13	4	1
Wheat straw	2½ tons	25	4	45	4	10
Corn, grain..........	100 bu.	100	17	19	7	1
Corn stover	3 tons	48	6	52	10	21
Corn cobs...........	½ ton	2		2		
Oats, grain..........	100 bu.	66	11	16	4	2
Oat straw...........	2½ tons	31	5	52	7	15
Clover seed..........	4 bu.	7	2	3	1	1
Clover hay...........	4 tons	160	20	120	31	117
Total in grain and seed..................		244[1]	42	51	16	4
Total in four crops......................		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

years 1906 to 1915, a yield of 77 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 79 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms. Thus, in the conversion of sufficient organic nitrogen into nitrate nitrogen for a 100-bushel crop of corn, the nitrous acid formed is alone sufficient to convert seven times as much insoluble tricalcium phosphate into soluble monocalcium phosphate as would be required to supply the phosphorus for the same crop.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

PERMANENT SOIL IMPROVEMENT

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land or returned after threshing (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

For the best production of seed in grain farming, alsike, sweet clover, or mammoth clover may well be grown. To avoid clover "sickness" it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease (such as cowpea wilt) these may alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil improvement. The first application may well be one ton per acre, and subsequently from one-half ton to one ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or

six tons per acre of raw phosphate containing 12 to 14 percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 to 12 cents a pound in steamed bone meal and acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 to 800 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought, as a rule.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and the nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has

not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. The mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly with other crop residues or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

The Potassium Problem

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first twenty-four years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of sixty years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed annually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for sixty years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium was applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of sixty years the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium on the wheat crop is becoming much more marked than that of sodium or magnesium; but this must be expected to occur in time where no potassium is returned in straw or manure and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field in Wayne county, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, in-

creased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure was applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit, in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value, but its decomposition yields organic acids.

If we remember that, as an average, live stock destroy two-thirds of the organic matter of the food they consume, it is easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

CALCIUM AND MAGNESIUM

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium; and with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone was applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 780 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every four or five years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

PHYSICAL IMPROVEMENT OF SOILS

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth and prevents the soil from running together badly; and as it decays it furnishes nitrogen for the crop and aids in the liberation of mineral plant food. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth. This decomposition is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal or the destruction of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter

content by plowing under manure or crop residues, such as corn stalks, straw. and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus. The nitrogen in a ton of corn stalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result. Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. This is well shown by the results of an experiment conducted by the Maryland Experiment Station, where 80 tons of manure were allowed to lie for a year in the farmyard and at the end of that time but 27 tons remained, entailing a loss of about 66 percent of the manure. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. Two tons of manure were exposed from April 29 to August 29, by the Canadian Experiment Station at Ottawa. During these four months the organic matter was reduced from 1,938 pounds to 655 pounds. To obtain the greatest value from the manure, it should be applied to the soil as soon as it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is to be planted. Whether the crop is corn or oats, it neces-

sarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to result, and if put in oats, the soil is so compact as to be unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

THIRTEEN YEARS' RESULTS WITH PHOSPHORUS ON THE UNIVERSITY OF ILLINOIS SOIL EXPERIMENT FIELD AT BLOOMINGTON, ON THE TYPICAL PRAIRIE LAND OF THE ILLINOIS CORN BELT

Year	Crop grown	Yield without phosphorus	Yield with phosphorus	Increase for phosphorus	Value of increase per acre
1902	Corn, bu.	37.0	41.7	4.7	$ 1.64
1903	Corn, bu.	60.3	73.0	12.7	4.44
1904	Oats, bu.	60.8	72.7	11.9	3.33
1905	Wheat, bu.	28.8	39.2	10.4	7.28
1906	Clover, tons	.58	1.65	1.07	7.49
1907	Corn, bu.	63.1	82.1	19.0	6.65
1908	Corn, bu.	35.3	47.5	12.2	4.27
1909	Oats, bu.	53.6	63.8	10.2	2.86
1910	Clover, tons	1.09	4.21	3.12	21.85
1911	Wheat, bu.	22.5	57.6	35.1	24.58
1912	Corn, bu.	47.9	74.5	26.6	9.30
1913	Corn, bu.	30.0	44.1	14.1	4.93
1914	Oats, bu.	40.6	45.0	4.4	1.23

Total value of increase in thirteen years.....$99.85
Total cost of phosphorus in thirteen years..... 32.50

Net profit in thirteen years.....$67.35

After the first year the phosphorus began to more than pay its annual cost; and during the second five-year period the increase produced by the phosphorus was worth almost as much as the total crops produced on the land not receiving phosphorus. In later years the need of organic manures with phosphorus has become apparent. (See pages 20 to 24 for more complete details.)

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

No. BULLETINS

76 Alfalfa on Illinois Soil, 1902 (5th edition, 1913).
*86 Climate of Illinois, 1903.
*88 Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois, 1903.
*93 Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils, 1904. (See No. 157).
94 Nitrogen Bacteria and Legumes, 1904 (4th edition, 1912).
*99 Soil Treatment for the Lower Illinois Glaciation, 1905.
*115 Soil Improvement for the Worn Hill Lands of Illinois, 1907.
123 The Fertility in Illinois Soils, 1908 (2d edition, 1911).
*125 Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois, 1908.
*145 Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils, 1910 (2d edition, 1912).
157 Peaty Swamp Lands; Sand and "Alkali" Soils, 1912.
177 Radium as a Fertilizer, 1915.
181 Soil Moisture and Tillage for Corn, 1915.
182 Potassium from the Soil, 1915.

CIRCULARS

*64 Investigations of Illinois Soils, 1903.
*68 Methods of Maintaining the Productive Capacity of Illinois Soils, 1903 (2d edition, 1905).
*70 Infected Alfalfa Soil, 1903.
*72 Present Status of Soil Investigation, 1903 (2nd edition, 1904).
*82 The Physical Improvement of Soils, 1904 (3d edition, 1912).
86 Science and Sense in the Inoculation of Legumes, 1905 (2d edition, 1913).
*87 Factors in Crop Production, with Special Reference to Permanent Agriculture in Illinois, 1905.
*96 Soil Improvement for the Illinois Corn Belt, 1905 (2d edition, 1906).
*97 Soil Treatment for Wheat on the Poorer Lands of the Illinois Wheat Belt, 1905.
*99 The "Gist" of Four Years' Soil Investigations in the Illinois Wheat Belt, 1905.
*100 The "Gist" of Four Years' Soil Investigations in the Illinois Corn Belt, 1905.
105 The Duty of Chemistry to Agriculture, 1906 (2d edition, 1913).
*108 Illinois Soils in Relation to Systems of Permanent Agriculture, 1907.
109 Improvement of Upland Timber Soils of Illinois, 1907.
110 Ground Limestone for Acid Soils, 1907 (3d edition, 1912).
*116 Phosphorus and Humus in Relation to Illinois Soils, 1908.
*119 Washing of Soils and Methods of Prevention, 1908 (2d edition, 1912).
*122 Seven Years' Soil Investigation in Southern Illinois, 1908.
123 The Status of Soil Fertility Investigations, 1908.
*124 Chemical Principles of Soil Fertility, 1908.
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3d edition, 1912).
*129 The Use of Commercial Fertilizers, 1909.
130 A Phosphate Problem for Illinois Land Owners, 1909.
*141 Crop Rotation for Illinois Soils, 1910 (2d edition, 1913).
142 European Practice and American Theory Concerning Soil Fertility, 1910.
145 The Story of a King and Queen, 1910.
*149 Results of Scientific soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois, 1911.
150 Collecting and Testing Soil Samples, 1911 (2d edition, 1912).
155 Plant Food in Relation to Soil Fertility, 1912.
*157 Soil Fertility: Illinois Conditions, Needs, and Future Prospects, 1912.
165 Shall we Use "Complete" Commercial Fertilizers in the Corn Belt? 1912 (4th edition, 1913).
167 The Illinois System of Permanent Fertility, 1913.
168 Bread from Stones, 1913.
181 How Not to Treat Illinois Soils, 1915.
185 A Limestone Tester, 1916.
186 I. The Illinois System of Soil Fertility from the Standpoint of the Practical Farmer. II. Phosphates and Honesty, 1916.

SOIL REPORTS

1 Clay County Soils, 1911.
2 Moultrie County Soils, 1911.
3 Hardin County Soils, 1912.
4 Sangamon County Soils, 1912.
5 La Salle County Soils, 1913.
6 Knox County Soils, 1913.
7 McDonough County Soils, 1913.
8 Bond County Soils, 1913.
9 Lake County Soils, 1915.
10 McLean County Soils, 1915.
11 Pike County Soils, 1915.
12 Winnebago County Soils, 1916.
13 Kankakee County Soils, 1916.

*Out of print.

Accessibility Statement

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If you are deaf, are hard of hearing, or have speech disabilities and you wish to file either an EEO or program complaint, please contact USDA through the Federal Relay Service at (800) 877-8339 or (800) 845-6136 (in Spanish).

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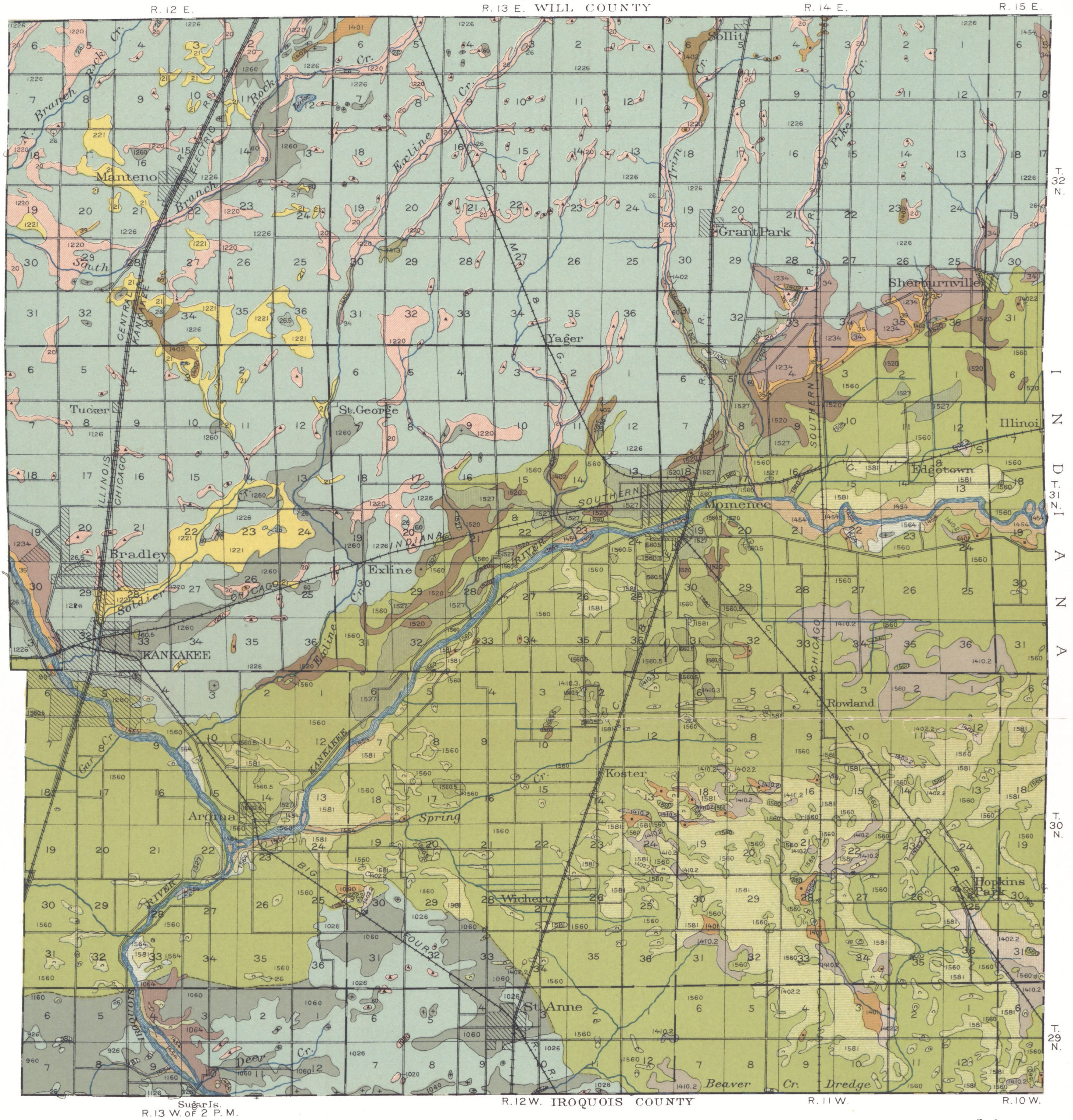


LEGEND

(a) UPLAND PRAIRIE SOILS

26, 926, 1026, 1126, 1226	Brown silt loam
26.5, 1226.5	Brown silt loam on rock
20, 920, 1020, 1120, 1220	Black clay loam
21, 1121, 1221	Drab clay loam
60, 960, 1060, 1160, 1260	Brown sandy loam
60.5, 1160.5	Brown sandy loam on rock
90, 1090	Gravelly loam

(b) UPLAND TIMBER SOILS

34, 1234	Yellow-gray silt loam
35, 1235	Yellow silt loam
64, 1064	Yellow-gray sandy loam

(c) TERRACE SOILS

1520	Black clay loam
1527	Brown silt loam over gravel
1528	Brown-gray silt loam on tight clay
1560	Brown sandy loam
1560.5	Brown sandy loam on rock
1564	Yellow-gray sandy loam
1581	Dune sand

(d) LATE SWAMP AND BOTTOM LAND SOILS

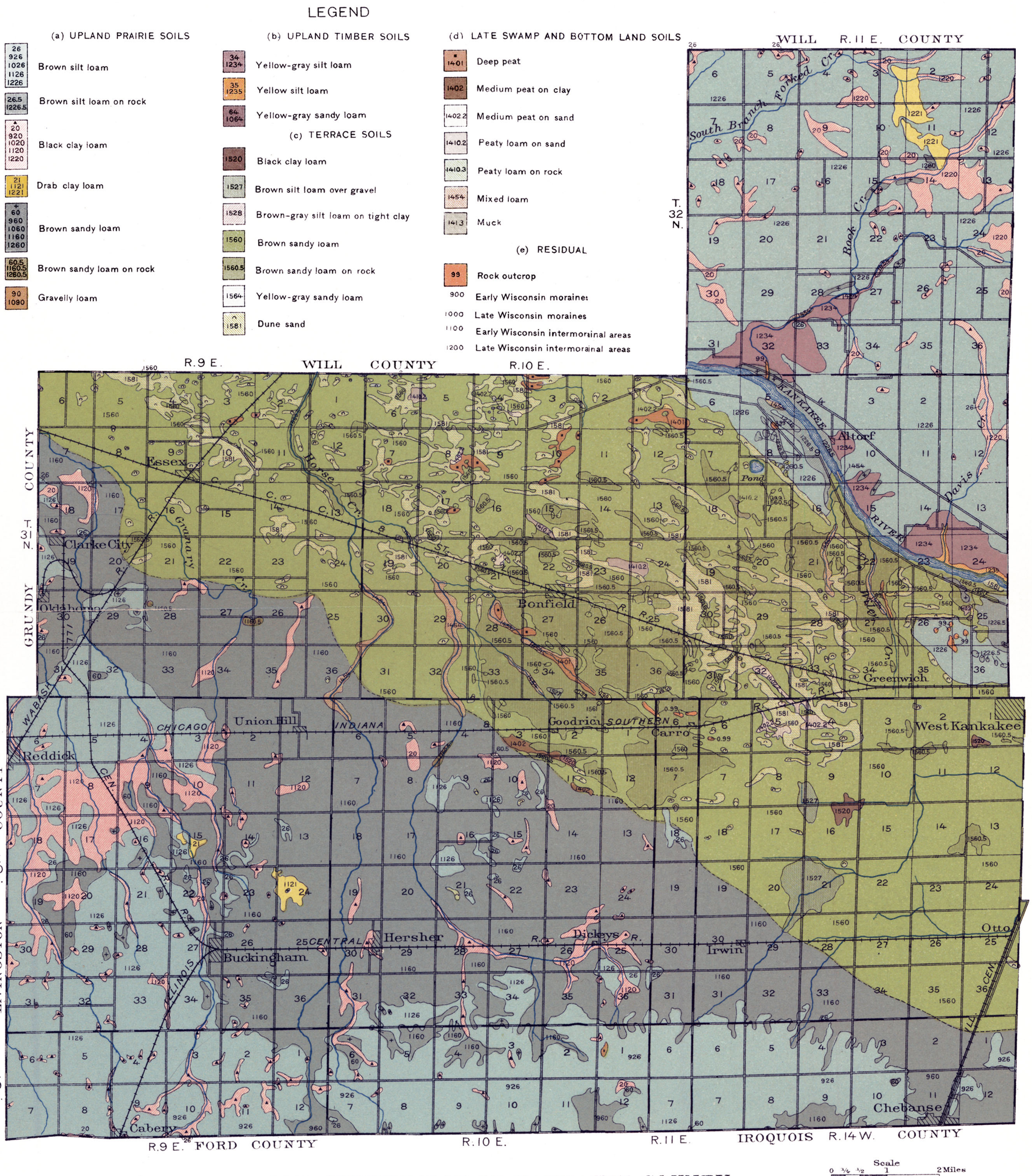
1401	Deep peat
1402	Medium peat on clay
1402.2	Medium peat on sand
1410.2	Peaty loam on sand
1410.3	Peaty loam on rock
1454	Mixed loam
1413	Muck

(e) RESIDUAL

99	Rock outcrop

900 Early Wisconsin moraines
1000 Late Wisconsin moraines
1100 Early Wisconsin intermorainal areas
1200 Late Wisconsin intermorainal areas

SOIL SURVEY MAP OF KANKAKEE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION



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